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BLM GUIDELINES
for
SAGEBRUSH/GRASS
and
PINYON-JUNIPER PLANT COMMUNITIES
to
INCORPORATE FIRE USE/MANAGEMENT
into
ACTIVITY PLANS
and
FIRE USE PLANS

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CREDITS

The efforts of a great many people went into these guidelines.

First and foremost is the Fire in Multiple Use Management R D & A Program at the Northern Forest Fire Laboratory at Missoula. This cooperative effort between the Bureau of Land Management and the Forest Service is the moving force which makes these guidelines possible. R D & A contracted and paid for the literature searches which resulted in Chapters V, VII, and VIII.

Dr. Henry Wright of Texas Tech University researched and wrote the state-of-the-art papers on prescribed fire in the sagebrush-grass and pinyon-juniper areas found in Chapter VIII.

The chapter on fire effects was supplied by Dr. Wright, Dr. Carlton Britton of the Squaw Butte Experiment Station, and Dr. Leon Neuenschwander of the University of Idaho.

The fire use plan chapter was taken from a paper by William C. Fischer, PLANNING FIRE USE: A Fire Management Approach, USDA Forest Service General Technical Report.

A portion of the format and information found in Chapters I and II was obtained from "A Guide for Prescribed Fire in Southern Forests" (Robley et al, 1973).

Chapter III, Smoke Management, is taken from a presentation made at Boise by Lester P. Mallory, Fire Weather and Air Pollution Service, N.O.A.A.

Information, both formal and informal, was obtained from the scientists at the Northern Forest Fire Laboratory, Missoula.

Some twenty people experienced in the fine art of prescribed burning assisted as instructors at the Cold Desert Workshop in Boise, Idaho, May 2-6, 1977.

Before these guidelines become finalized, the Shoshone, Idaho; Elko, Nevada; and Cedar City, Utah BLM Districts will put them to the test by planning, executing, and evaluating some prescribed burns. After the testing, the guidelines will be revised, as necessary, and distributed to the remaining BLM districts in the sagebrush-grass and pinyon-juniper areas.

INTRODUCTION

Past research and practice have shown that, under the proper conditions, fire can be an effective tool in resource management. Recent research has made a start at more precisely defining the proper conditions and more accurately quantifying results or impacts.

The change from fire control to fire management is one which must be done carefully and with detailed planning. With good planning and carefully written prescriptions, the manager can recognize situations where fire may have a potential for meeting management objectives and provide administrative necessities required to take advantage of favorable situations. HOWEVER, after a fire starts, it is a little late to plan and decide what should be done--you really have little choice but to put out the fire.

The BLM planning system is being revised to more adequately reflect fire management considerations in the planning process. URA and MFP procedures will be revised in FY 1977 and FY 1978. These guidelines presume that an MFP has been completed on the area and will concentrate on the activity and project plan levels. The guidelines also presume that the MFP has not laid down hard and fast constraints against the use of fire on the area to be planned.

Chapter I

BACKGROUND

Reasons for Prescribed Fire in Resource Management

There are a number of reasons for using prescribed fire in resource management. The following is a general discussion of those reasons. Specifics will depend on activity plan objectives.

Reduce Hazardous Fuels--

Prescribed fire is the most practical management tool to use where combustible fuels accumulate. Wildfires that burn into areas where fuels have been reduced by prescribed burning cause less damage. Prescribed burning for fuel reduction has no set time interval. However, degree of fire occurrence, risk, and fuel buildup will serve as guides in determining burning intervals.

When prescribed burning to reduce hazardous fuels, the objective is to break up the fuel continuity. Fuel reduction on 75-80% of the area should accomplish this.

Prepare Sites for Seeding--

Prescribed burning is useful in preparing a seedbed for herbaceous species where brushfields or solid stands of juniper now exist. It will expose mineral soil, reduce competition, and reduce or eliminate obstacles to seeding equipment.

Improve Wildlife Habitat--

Beneficial results from burning may include increase in yield and quality of herbage (particularly forbs) and browse, and creation of openings for feeding, travel, and dusting. One can also produce habitat which is optimum for a given wildlife species. This can be done by interrupting the process of plant succession to produce the seral stage most favorable to a particular species of wildlife. However, special care should be taken not to destroy critical areas such as large units of unburned brush for cover for big game or key cover for upland game birds.

Proper size, frequency, and time of burns are critical to success in the use of fire in managing wildlife habitat. Prescriptions should recognize the biological requirements of the preferred wildlife species as well as the vegetative conditions of the area.

Reduce Density and Cover of Brush

With improper grazing and protection from fire many stands of undesirable brush and trees have gradually gotten thicker and taken up space that was once occupied by grasses, forbs, and desirable shrubs. In many cases fire can be used to reverse this trend.

Improve Forage Quality, Accessibility, and Yields--

Vegetative manipulation by prescribed burning coupled with intensive livestock management can greatly enhance livestock forage. A properly burned area can realize a reduction of the less palatable plants and a rather dramatic increase of the more desirable species. Also, in areas of dense brush, the

stand can be opened making travel for livestock, especially sheep, much easier. Shrubs out of reach for livestock and game can become easily accessible with resprouts after a burn.

The point must be made that proper management of livestock is critical to achieving desired results following a burn, for without it, the area will soon return to its original condition.

Enhance Appearance--

Under some circumstances, prescription burning can be used for recreation and esthetic purposes to maintain parklike stands (trees), emphasize vegetative type changes, increase numbers and visibility of flowering annuals and biennials, and maintain open spaces. A diversity of vegetative types attracts a wider variety of bird and mammal species and makes them more visible.

There is great potential for the use of fire in managing the landscape and enhancing scenic values, and areas so treated have high public exposure.

Improve Watersheds--

Conversion from brush to grass can be effective in reducing flash runoff, increasing percolation, opening springs, and increasing groundwater supply.

Fire Effects

Environmental Effects--

Prescribed burning has direct and indirect effects on the environment. To properly prescribe and then evaluate both benefits and damages of a burn, it is necessary to know how fire affects vegetation, soil, water, air, and wildlife. Timing of burns and burning techniques may be used to obtain a wide range of fire effects.

Effects on Vegetation--

Prescribed fire may injure or kill only part of a plant or the entire plant, depending on how intense the fire burns and how long the plant is exposed to heat. In addition, the plant may have features that protect it from heat (bark on trees, growth form of grasses, etc.). Burning after recent rains will help protect susceptible bunchgrasses and shrubs from fire damage. When plants are actively growing they are more easily damaged by prescribed fire. The least fire damage occurs during a plant's dormant season.

Effects on Soil--

Specific effects on soil vary greatly. Frequency, duration and intensity of fire, and soil characteristics must all be considered. Prescribed burning normally causes little or no detectable change in amount of organic matter in surface soils. Typical prescribed fire temperatures will not cause changes in properties of mineral soil particles, but burning windrows of pinyon-juniper or high-intensity wildfires may produce enough heat to cause losses of soil organic matter and changes in the structure of soil clays.

Burning may indirectly result in increased nitrogen fixation in the soil and thus compensate for nitrogen loss to the atmosphere that results from burning the litter layer.

A major concern of the land manager is how fires affect surface runoff and soil erosion. For most flat, sandy soils there is little danger of erosion by water when vegetative cover is reduced. However, in some areas, wind can be a problem. Burning should not be done on highly erosive soils.

The main effect of prescribed burning on the water resource is the possibility of increased runoff carrying suspended soil particles, dissolved inorganic nutrients, and other materials into adjacent streams and lakes. This possibility must be considered when planning a burn in steep topography near live water.

Effects on Air--

Combustion of fuels by prescribed fire may contribute to changes in air quality. However, on a regional scale, air quality would be affected only when many acres are burned on the same day. Local problems can be avoided by burning only for short periods of time under the proper weather conditions. In general, the relatively small amounts of gaseous emissions from prescribed fire do little damage to air quality and are not a serious threat. Particulates, however, are of special concern to the prescribed burner because of the reduction in visibility caused by smoke. The extent of the problem depends on the amount and type of fuel consumed, fuel moisture content, and the rate of fire spread as determined by the timing and type of firing technique used.

Effects on Wildlife--

The direct effects of prescribed fire on wildlife include destruction of nesting sites and possible kill of birds, reptiles, or mammals trapped in the fire. Fortunately, prescribed fires can be planned for times when nests are not being used. Prescribed fires are not usually large enough, hot enough, or fast-spreading enough to trap and kill wildlife if conducted properly.

The major effects on wildlife are indirectly beneficial and concern changes in food and cover conditions. Prescribed fire can increase edge effect and browse material, and also increase forbs and grasses favored by many species.

Fish populations can be adversely affected. Vegetation along stream edges should be excluded from a prescribed burn and allowed to protect the channel from siltation and increased water temperatures that occur when all shade is removed.

Effects on Esthetics--

The effect of prescribed burning on esthetics varies according to the way the effects are perceived by the individual. What may be considered an improvement in the scenic beauty by one may be considered undesirable by another.

Generally, the immediate effect on esthetics is undesirable. However, that should change over time in most areas, especially with a low intensity burn.

General Weather Considerations

Important Weather Elements--

A general understanding of the separate and combined effects of several weather elements on the behavior of fire is needed if the prescribed burner is to plan and execute a good burn. Wind, relative humidity, temperature, rainfall, and airmass are the more important elements to consider. These factors influence fuel moisture and rate of spread which must be considered in carrying out the prescription.

Sources of Weather Information--

Ordinarily, three sources of weather information are available.

National Weather Service

Fire Danger Rating Stations

Local Observations

Local National Weather Service offices will furnish weather forecasts and outlooks. The services of fire-weather forecasters are available for spot forecasts on the area to be burned.

All BLM Districts have a number of fire weather gathering stations from which important information can be obtained.

Field observations of weather should be made at or near the prescribed burn area before and during burning. Such observations serve as a check on the applicability of the forecast and keep the burning crew up-to-date on any changes or effects of local influences. Handy belt weather kits, which contain a psychrometer and windspeed measuring instruments, are available. With these kits, and by observing cloud conditions and other weather indicators, a competent observer can obtain a fairly complete picture of current weather.

Wind--

Prescribed fires behave in a more predictable manner when some wind movement is present. Ideal conditions occur when both windspeed and direction are steady.

Perhaps of greater importance than windspeed is the length of time the wind blows from one direction. The most critical areas, with regard to fuel and topography, should be burned when persistent wind directions occur. The relatively easy burns may be attempted under less desirable wind conditions.

Relative Humidity--

Relative humidity is an expression of the actual amount of moisture in the air compared to the total amount the air is capable of holding at that temperature and pressure. A temperature rise of 20 degrees that might occur from sunrise and mid-afternoon reduces the relative humidity by about half, and a temperature drop in early evening causes relative humidity to rise. When a cold

front passes over an area, the temperature drop is usually accompanied by a drop in humidity. The lower humidity is the result of a change in airmass from warm and moist to cold and dry.

The moisture content of fine fuel responds rapidly to changes in relative humidity. However, because there is a timelag involved for heavier fuels to achieve equilibrium with the moisture condition of the surrounding atmosphere, and because previous drying or wetting regimes can influence fuel moisture, relative humidities by themselves cannot be relied upon completely for predicting the success or failure of a burn.

Rainfall--

Rainfall affects fuel moisture and soil moisture. In winter, rain or snow may be fairly easy to forecast, but in summer, when shower activity prevails, the prediction of rainfall at individual locations becomes very difficult. For this reason, the prescribed burner needs some idea of amounts of rain falling on the area to be burned. For range burning, however, the most important factor is to burn when the soil is moist and to wait for 4 or 5 days after a major storm before burning woody fuels.

Fine Fuel Moisture--

Fine fuel moisture is not a weather element but is influenced by relative humidity, rainfall, and temperature.

Relative humidity can control moisture content of fuels up to about 35%. Liquid moisture in the form of rain, snow, or dew must contact the fuel for moisture to go above 35%. The increase depends on duration as well as amount of precipitation. For example, 1 inch of rain occurring in 2 hours will not produce as large a moisture gain as 1 inch falling over a 12-hour period. Different types of fuels may reach different moisture content levels under the same humidity conditions. At 50 percent relative humidity, some grasses may contain 8% moisture, some brush leaves may have a moisture content as high as 10-14%. Because of these natural variations, any moisture values recommended are only guidelines. On-the-ground knowledge of fuels must be incorporated into planning the prescribed burn.

Airmass Stability--

Atmospheric stability is the resistance of the atmosphere to vertical motion. A prescribed fire generates vertical motion by heating the air, but the strength of convective activity over a fire is affected by the stability of the airmass. Strong convective activity will increase the indrafts into the fire and may result in erratic fire behavior, but give good dispersal of smoke.

When the atmosphere is stable, a small decrease in temperature occurs with an increase in altitude. Under very stable conditions, inversions may develop in which temperature actually increases with height. Stable air tends to restrict convection column development and produces more uniform burning conditions. However, combustion products are held in the lower layers of the atmosphere, especially under temperature inversions, and visibility may be reduced because of smoke accumulation. Do not burn under these conditions. When the atmosphere is unstable, there is a large decrease in temperature with

height. Once air starts to rise, it will continue to rise and strong convection is helpful in venting smoke into the upper atmosphere. In extreme cases, the effect of air mass instability on fire behavior may result in erratic spread rates, spotting, and crowning.

Forecasts of low-level stability, inversion layers, or unstable conditions may be obtained from fire-weather forecasters. Local indicators at the fire site should also be observed. Indicators of stability are steady winds, clouds in layers, and poor visibility due to haze and smoke hanging near the ground. Unstable conditions are indicated by dust devils, gusty winds, clouds with vertical growth, and good visibility. Dust devils usually form when there is very little air movement. These are not desirable conditions for prescribed burns. Burn with steady winds.

Chapter II

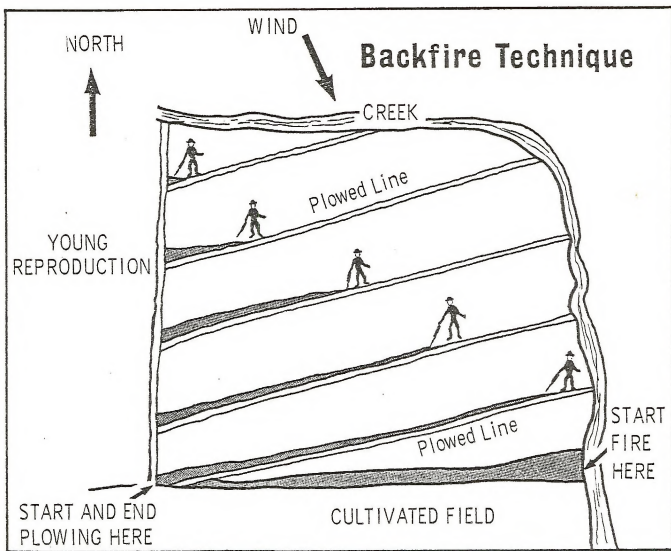
FIRING TECHNIQUES

General

Various firing techniques are available to help accomplish a burn objective under different weather, topography, and fuel conditions. Burning objectives, fuels, and weather factors must be correlated closely with the proper firing technique to prevent harmful effects to the resources.

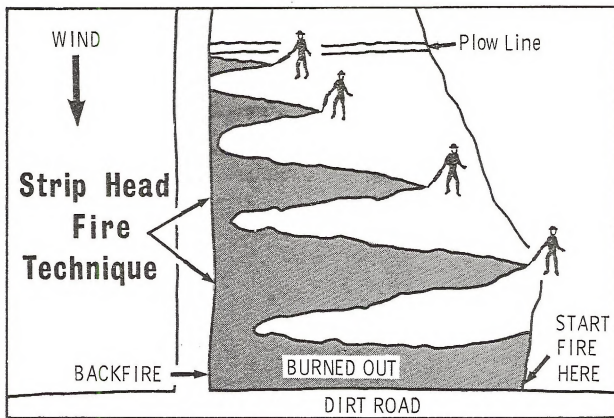
Based on behavior and spread, fires either move in the same direction as wind (head fire), in the opposite direction to wind (backfire), or at a right angle to wind (flank fire). The head fire is the most intense because of its faster spread rate (10 to 20 chains per hour), wider burning zone, and greater flame lengths. The backfire is the least intense--having slow spread rates (1 to 3 chains per hour), a narrow burning zone, and short flames. The flank fire intensity is intermediate.

When slight variations in fuel volumes or prescribed weather conditions occur, consider combining two or more firing techniques to achieve a desired result.



Backfire

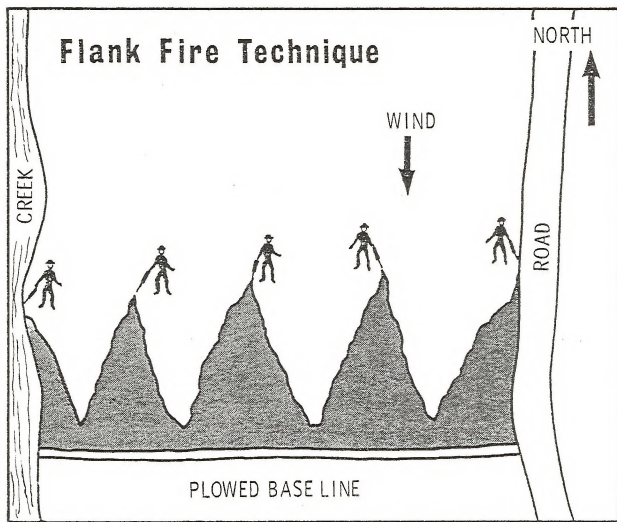
The backfire technique consists primarily of backing fire into the wind. Fire is started along a prepared baseline, such as a road, plowed line, black line, stream, or other form of barrier, and allowed to back into the wind. Research indicates that variations in windspeed have little effect on the rate of spread of fire burning into the wind. Normally, such fire proceeds backward at a speed of from 1 to 3 chains per hour. This technique is perhaps the easiest and safest type of prescribed fire, provided a steady wind (speed and direction) prevails. It lends itself to use in heavy fuels. Some disadvantages are the time-consuming progress of the fire and the need for interior plowing at frequent intervals, usually every 10 to 20 chains, to insure burning out of the strips. Stronger wind velocities (4 to 10 mi/h, ground level) are desirable in utilizing this firing technique so that smoke is well dissipated. Burning on slopes has an effect similar to wind on rate of spread. Downslope fires, for example, would give much the same results as backfires in flat country.



Strip-Head Fire

The strip-head fire involves setting a line, or series of lines, of fire upwind of a firebreak in such a manner that no individual line of fire can develop to a high energy level before it hits either a firebreak or another line of fire. The strips vary in width depending on type, amount, and distribution of fuel and desired results. Usually, strips should be about 1 to 3 chains apart. Frequently, a combination of strip-head fire and backfire is used to treat an area. The base control line would be treated with a backfire, then the remainder of the area treated with strip-head fires. Compensation for minor wind direction changes can be made by altering the angle of strip fire with the baseline. Also, adjustments for fuel density and composition can be made by altering strip widths. This method permits quick firing and smoke dispersal under optimum conditions.

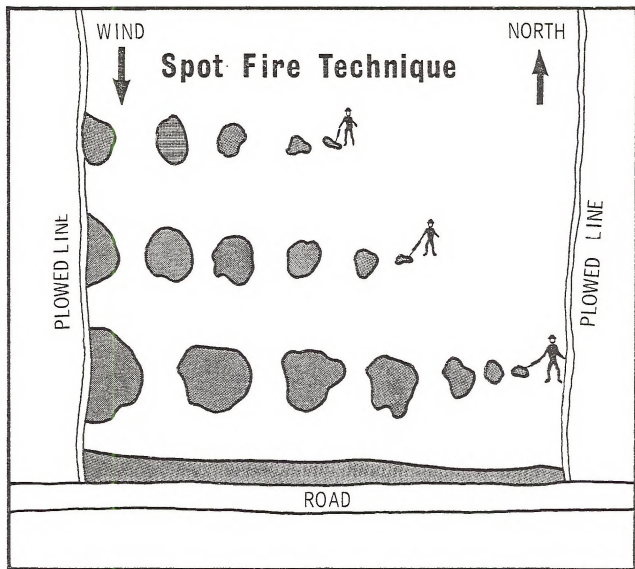
Occasionally, on small areas with light and even fuel distribution a head fire may be allowed to move over the entire area without stripping to better accomplish the objective. Where this method is usable, it would cut down on the areas of increased fire intensity that would occur at junctures of strip fires burning together. CAUTION - Be sure the fire will not escape control. Burn out a strip down-wind with a backfire wide enough to control the head fire.



Flank Fire

The flank fire technique consists of treating an area with lines of fire set into the wind which burn outward at right angles to the wind. This technique also requires considerable knowledge of fire behavior, particularly if used by itself. It is used quite often to secure the flanks of a strip-head fire, backfire, or other methods as they progress. It is sometimes used to supplement a backfire in light fuel areas or under more humid weather conditions.

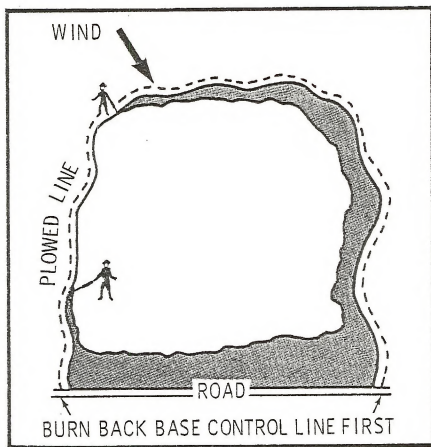
This method of firing can stand little variation in wind direction and needs expert crew coordination and timing. It is useful on a small area or to facilitate burning a large area in a relatively short time.



Spot Fire

The technique of spot firing is an exact procedure which requires considerable experience by the prescribed burner. This method employs a series of small spot fires which burn in all directions as they come together, minimizing the possibility of any one spot gaining sufficient momentum to start a hot run. Timing and spacing of the individual fire spots are the keys to successful application of this method.

Care should be taken not to space spots closer than 2 to 3 chains which would create more junction zones of increased intensity, nor too far apart allowing individual spots to build up hot fire heads. A skilled crew can treat a large area in a short time using this technique. Inexperienced prescribed burners should utilize some other technique until they gain considerable experience in fire behavior. This method can be used with light, variable winds. CAUTION - variable winds may be an indication of instability.



Ring Fire Technique

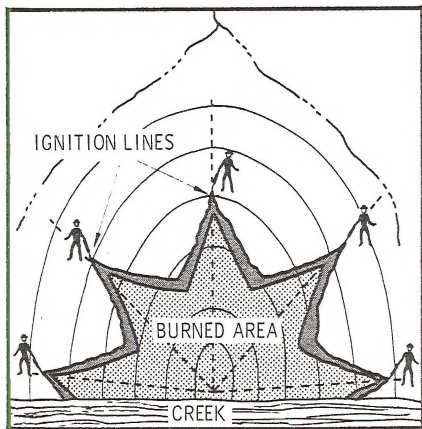
Center and Circular (or ring) Firing

This method of burning is used on areas where a relatively hot fire is needed to reduce or eliminate heavy brush or debris.

As with other burning techniques, a base control line, usually on the downwind side of the burn area, is made secure with back and flank firings. Once the baseline is secured, the entire burn area is circled with fire and allowed to sweep over the area. Often, during periods of light wind, one or more spot fires near the center of the area can assist in pulling the outer circle of fire toward the center. This firing method can generally be used in any season--weather conditions are not as critical. However, caution is in order, particularly when weather conditions border on the unstable. This type of fire is conducive to developing strong and often violent convection columns, spotting possibly up to 1 mile at times.

Pile and Windrow Burning

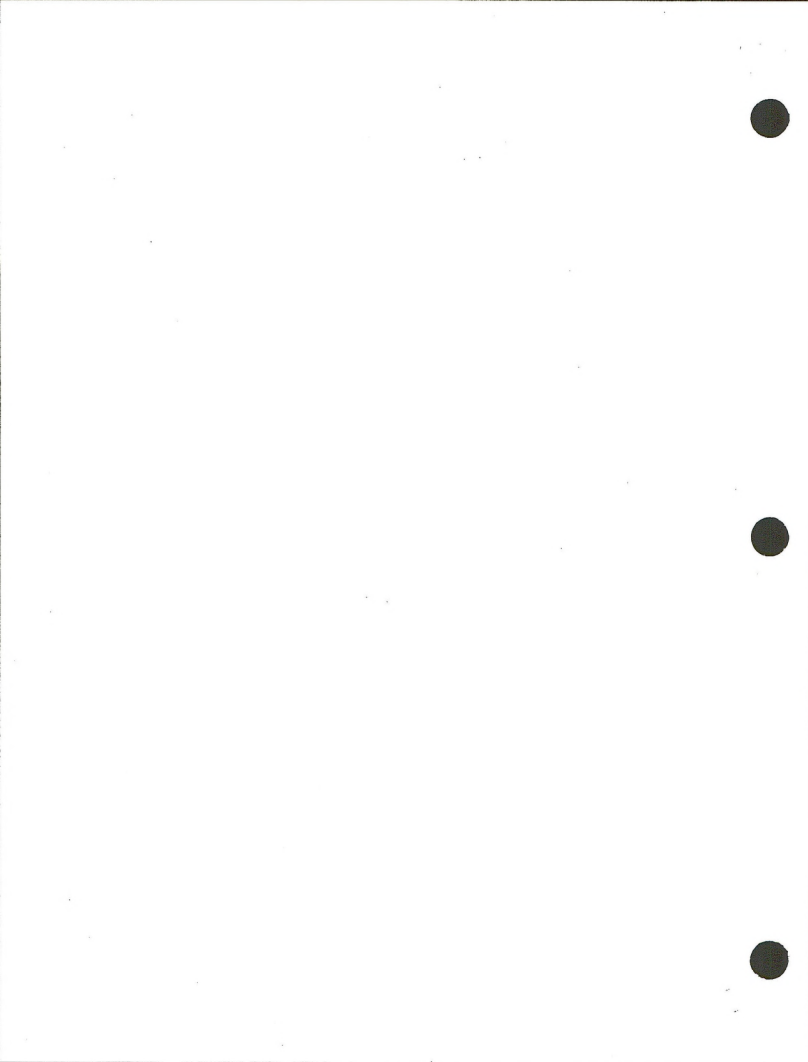
Due to the character and placement of fuel, techniques used in burning debris piles and windrows are more or less fixed. However, it is highly recommended that every precaution and every prerequisite for the best weather conditions conducive to good smoke dissipation in open burning also be followed in fixed burning situations, such as pile and windrow burning. Piles should be as free of soil as possible to speed up combustion.



Chevron Ring Technique

Chevron Burn

This technique of prescribed firing is designed for use in hilly areas to fire ridge points or ridge ends. Lines of fire should be started simultaneously from the apex of a ridge point, and progress downhill. Basically, it involves a flank fire concept except that the lines of fire are not parallel. Any two lines of fire converge at a point rather than along a line, resulting in the junction zones or areas of increased intensity remaining small. The chevron technique alone is not suited to most topography and should be used only in combination with other techniques.



Chapter III

by Lester P. Mallory

SMOKE MANAGEMENT

Prescribed burning, however useful it may be in accomplishing certain resource objectives, can contribute to air pollution. The use of prescribed burning carries with it an obligation to eliminate or minimize any adverse environmental effects. Listed below are some guidelines to observe in reducing the impact from smoke:

1. Have defensible objectives.--Be sure you have clear resource objectives and have considered the impact on the total environment - both onsite and offsite.

2. Obtain and use weather forecasts.--Weather information and fire-weather forecasts are available to all resource managers. Be sure to use them. Such information is needed to determine what will happen to the smoke, as well as to determine the behavior of the fire.

3. Don't burn during pollution alerts or temperature inversions.--Smoke will tend to stay near the ground and will not disperse readily. Many fire-weather forecasters include this in their regular forecasts.

4. Comply with air pollution control regulations.--Know the regulations when you make the prescription. Check with the appropriate State agency.

5. Burn when conditions are good for rapid dispersion.--The atmosphere should be slightly unstable so smoke will rise and dissipate - but not so unstable as to cause a control problem. Again, your fire-weather forecaster can help.

6. Determine the direction and volume of smoke.--This is especially important near highways and populated areas. Smoke management guidelines will help in making these determinations.

7. Use caution when near or upwind of smoke-sensitive areas.--Burning should be done when wind will carry smoke away from heavily traveled roads, airports, and populated areas.

8. Notify the local fire control office, nearby residents, and adjacent landowners.--This is not only common courtesy, but a requirement in many areas. Keep the publics informed. They should know whether smoke is from a wildfire or a prescribed burn. Prior notification will give you advance notice of any adverse public reaction--such as people with respiratory ailments, washday, etc.

9. Use test fires to confirm smoke behavior.--Set these in the area proposed for burning, away from road or other "edge" effects.

10. Use backfires when possible.--Backfires result in more complete consumption of fuel and produce less smoke. Even though slower and more expensive, fewer pollutants are put into the air and visibility is less restricted.

11. Burn in small blocks.--The larger the area being burned, the more visibility is reduced downwind and the higher the concentration of particulates put into the air. However, it may be better to burn all the area needed when weather conditions are ideal for rapid dispersion of smoke.

12. Mopup along roads.--Burn out and start mopup along roads as soon as possible to reduce impact on visibility.

13. Be cautious of nighttime burning.--Predicting smoke drift and visibility is more difficult at night. The wind may lessen or die out completely and smoke will tend to stay near the ground. Burn at night only when you have a definite forecast of optimum conditions.

14. Have an emergency plan.--Be prepared to control traffic on nearby roads if wind changes direction. Be prepared to stop a prescribed burn if it is not burning according to plan or if weather conditions change.

Chapter IV

INCORPORATING FIRE MANAGEMENT IN ACTIVITY PLANS

In reviewing the BLM Manual instructions for the preparation of activity plans for Range, Wildlife, and Watershed, an underlying theme comes through loud and clear. After the objectives of the plan are established, the vegetation is to be managed and/or manipulated to achieve those objectives. This means management in favor of some species of vegetation and against others. Or, it may mean maintaining the vegetative composition in adjacent areas in a variety of seral stages. Once the objectives are set and the manager decides on which species he wants to encourage and which he wants to discourage, he can use these guidelines and decide whether and how he wants to use fire as one of the many land treatment tools available to him in achieving those objectives.

Two principal factors must concern him in this process--fire effects and fire behavior.

Fire Effects

Fire may have a beneficial or detrimental effect on vegetation, depending upon the management objectives. The effect varies by species and by season of the year. Fire may enhance a desirable species while damaging an undesirable. In other cases, the reverse may be true. For instance, under certain conditions, bluebunch wheatgrass can increase in abundance after a fire while big sagebrush will decrease dramatically. On the other hand, antelope bitterbrush may be severely damaged while rabbitbrush increases. See Chapter V for an in-depth discussion of fire effects in your area.

Fire Behavior

If the manager is to attain the desired fire effects, he must have an appreciation of fire behavior and the various factors that govern how a fire burns. He will want the right fire at the right time to accomplish the stated objectives. He will also want to guard against escapes and disaster fires. Consultation with the District Fire Management Officer will help on this subject.

Procedures

Chapter V contains writeups on several plant species found in your area. The information is not all inclusive, but should cover most situations. As experience adds to his knowledge, the manager is encouraged to produce additional writeups for his area.

In order to determine whether fire can be used on an area and if so, what kind of a fire it should be, the manager should do the following:

1. Examine the fire effects writeups for the plants pertinent to the area.
2. Summarize key words on a table or matrix if necessary.
3. From this array, the manager should be able to make an informed judgment concerning the use of fire. If his decision is strict fire control, that should be so stated in his activity plan and in the Fire Management Activity Plan.

If fire use is the decision, he should spell out in the activity plan the conditions under which it is to be done:

1. Schedule (i.e., every 15 years after initial burn).
2. Season (spring, summer, fall, winter, or a particular month).
3. Intensity desired (i.e., clean burn--prefer islands left, etc.).
4. Restrictions for favoring certain plants (i.e., burn only under certain soil moisture conditions to favor sprouting of bitterbrush).

Also, if fire use is contemplated, it must be discussed in any EAR/ES which is written on the activity plan. The environmental effects can be:

1. Short range -

Discuss such things as smoke, temporary denuding of the landscape (esthetics), temporarily exposed bare soil, etc.

2. Long range -

Discuss such things as possible diminution or eradication of some species, dangers in slow recovery of vegetation and erosion potential, possible permanent change in esthetics (mosaic appearance instead of uniform vegetation), etc.

The environmental effects may be good, bad, or neutral, depending upon the plan objectives, but there will be effects.

The pertinent portions of the activity plans (AMP, HMP, etc.) should be used in the District Fire Management Activity Plan.

Chapter V

FIRE EFFECTS

Unabridged Fire Effects Data For Each Individual Species

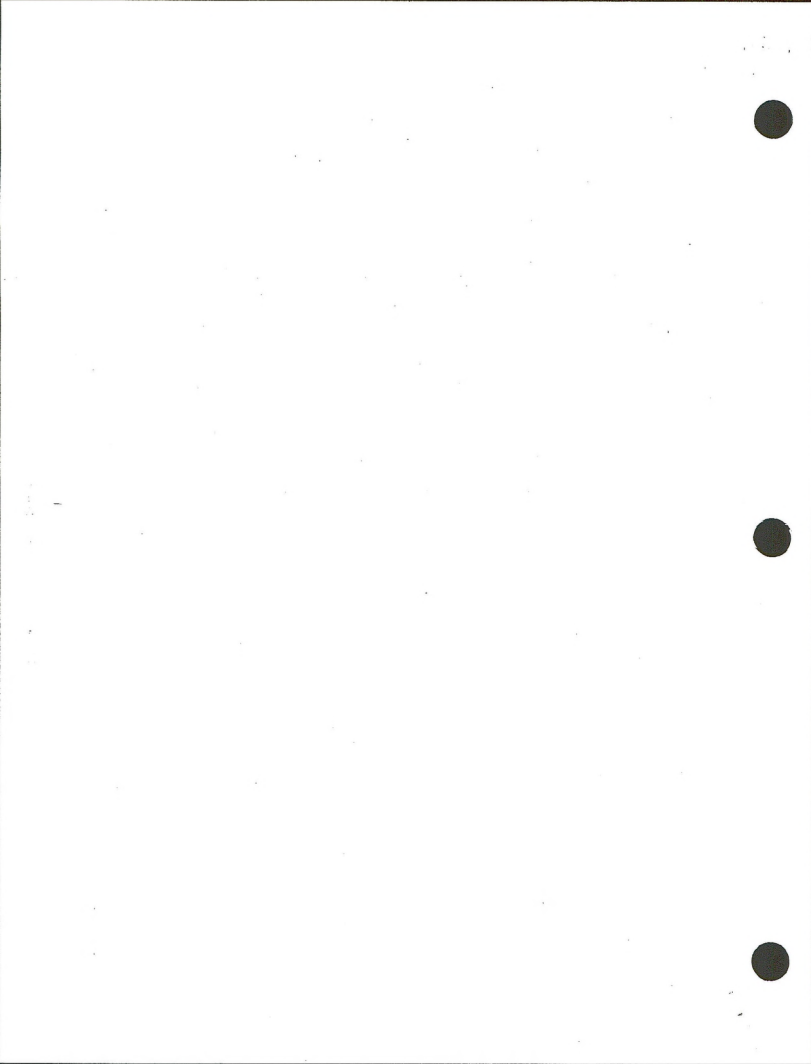
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RESPONSE OF GRASSES TO BURNING

Bluegrasses

In general bluegrasses (*Poa* sp.) are slightly damaged by burning. Wright and Klemmedson (1965) observed no change in basal area of Sandberg bluegrass (*Poa sandbergii*) during any season regardless of the size of plants. These plants were mature, dry, and contained little fuel in the crown of the plant. Tisdale (1959) reported some damage to Sandberg bluegrass in communities with 7 to 14% sagebrush cover. This damage was possibly caused by plants being old, pedestaled, and having an accumulation of litter in the crown. High mortality has been observed in southern Oregon when plants are pedestaled (Hammersmark, 1977). An August wildfire in northeastern California caused decreases in plant numbers (Countryman and Cornelius, 1957). Moomaw (1957) found no damage in eastern Washington. Uresk et al (1976) measured a 57% decrease in basal area of cusick bluegrass (*P. cusickii*) after an August wildfire.

On the upper Snake River plains of Idaho, Nevada and Sandberg bluegrass showed little change in production for 3 years after burning (Harniss and Murray, 1973). This initial static period was followed by increased yields with the burned area producing about 1.5 times more than the unburned. Thirty years after burning, yield was substantially lower on both burned and unburned areas, although the burned area was producing twice as much as the unburned. Big bluegrass (*P. ampla*) is not mentioned in the available literature but, due to larger clone size and greater potential accumulation of litter in the crown, it would be expected to incur slightly more damage than other bluegrasses.

Cheatgrass

Cheatgrass (*Bromus tectorum*) is not appreciably affected by burning although production may be reduced for the first year. Abandoned fields on the Snake River plains dominated by cheatgrass were changed to primarily tumble-mustard (*Sisymbrium altissimum*) and Russian thistle (*Salsola kali*) after burning for 2 to 3 years. Cheatgrass dominated these fields during the next 2 to 3 years (Piemeisel, 1938). Burning was found to reduce stands of cheatgrass in eastern Washington, presumably because of seed destruction (Robocker et al, 1965). Depending on the intensity of burn, germinable cheatgrass seed can be reduced 80 to 99% (Young et al, 1976). This reduction left from 3 to 33 germinable seeds per square foot, but as few as 5 cheatgrass seeds per square foot moderately reduced establishment of crested wheatgrass. June and July burns reduced cheatgrass plant numbers to 14 and 11 per square foot compared to 41, 45, and 124 plants per square foot on August, October, and November burns, respectively near Boise, Idaho (Pechanec and Hull, 1945). These reductions are only temporary, for annuals produce abundant seed the year after a burn. Early summer burns will kill perennial grasses and allow cheatgrass to increase sharply.

Cheatgrass can rapidly occupy a burned area if only a few seeds are available (Countryman and Cornelius, 1957). Barney and Frischknecht (1974) reported that cheatgrass cover declined during the first 22 years after fire, then stabilized. This cover change varied from 12.6% on 3 year old burns to 0.9% on the oldest burns.

Idaho fescue

The majority of evidence indicates that Idaho fescue (*Festuca idahoensis*) is severely damaged regardless of when or where it is burned (Pechanec and Stewart, 1944; Blaisdell, 1953; Harniss and Murray, 1973). After a period of 30 years, Idaho fescue was just approaching its former abundance on the upper Snake River plains (Harniss and Murray, 1973). As a result of a summer wildfire in eastern Washington, Idaho fescue mortality was 27% with a reduction in basal area of 50% (Conrad and Poulton, 1966). In northeastern California, basal area of Idaho fescue was reduced approximately 80% by an August wildfire (Countryman and Cornelius, 1957).

Mid-May burns in eastern Oregon resulted in 30% mortality and a 48% reduction in basal area (Britton and Sneva, 1977). However, when the plants were dormant in the fall, no mortality resulted although there was a 34% reduction in basal area. Phillips (1977) observed that in central Oregon, wildfires were more damaging to Idaho fescue on coarse soils as compared to fine textured soils. Good soil moisture was found beneficial to Idaho fescue survival during spring burns in Nevada (Beardall and Sylvester, 1975).

Indian ricegrass

Indian ricegrass (*Oryzopsis hymenoides*) is important in sagebrush-bunchgrass communities only in localized situations. As such, it has not been the subject of intensive investigations. Pechanec and Stewart (1944) mention it as being slightly damaged and slow to increase after burning.

In west-central Utah, Indian ricegrass was found to be an important species on burned areas (Barney and Frischknecht, 1974). Therefore, it probably has good survival characteristics. Spring burning in Utah did little damage to Indian ricegrass with growth initiation about 3 weeks after burning (Jensen, 1977). Summer wildfires in Nevada cause reductions in basal area, but little mortality was noted (Wagner, 1977).

Junegrass

In eastern Oregon, junegrass (*Koeleria cristata*) has been found to be one of the most fire resistant perennial bunchgrasses (Britton and Sneva, 1977). Burning in mid-May reduced basal area by 32% with 20% mortality. During mid-June just after seed set, basal area was reduced 18% with no mortality while burning in mid-October produced only slightly more damage. This lack of appreciable damage is probably due to the relative small size of the typical junegrass clone.

Fall burning in North Dakota increased the frequency of junegrass on a sandy soil (Dix, 1960). Twelve years after burning in Idaho, junegrass yield was higher on burned areas as compared to unburned areas (Blaisdell, 1953). Countryman and Cornelius (1957) reported a slight decrease in junegrass due to a wildfire although the sample was too small for adequate interpretation.

Needlegrasses

Most needlegrasses (*Stipa* sp.) are damaged by burning, especially during the first year. Harniss and Murray (1973) reported a severe reduction the first year after burning needle-and-thread (*Stipa comata*). Season of burn rather than burning intensity or plant size was found to be the most critical factor in mortality of needle-and-thread (Wright and Klemmedson, 1965). June burns killed all of the small and 90% of the large plants. In July, 20% of the burned plants died with no mortality for August treatments. Among large plants, the average basal area reduction after June, July, and August burns was 99.6, 96, and 68%, respectively. The reduction in basal area for the small plants following June and July burns was 100 and 82%, respectively. Small plants burned in August exhibited some thinning of the crown. This damage was related to the intolerance of needle-and-thread to herbage removal and the large amounts of dead material per unit basal area (Wright, 1971). In western North Dakota, fall burning decreased needle-and-thread frequency by 11% on sandy soils but increased frequency by 10% on a clay loam soil. Observations in southern Idaho indicate that with moderate grazing treatments needle-and-thread requires 4 to 8 years after burning to fully recover.

Twelve years after burning, Blaisdell (1953) observed that needle-and-thread and Columbia needlegrass (*S. columbiana*) were not significantly affected by any intensity of burn, although the former produced 10 to 26 pounds more per acre on burned than on unburned range. Western needlegrass (*S. occidentalis*) was reduced the first year after an August wildfire in northeastern California (Countryman and Cornelius, 1957). By the third year after burning, western needlegrass had almost doubled in basal area as compared to the unburned area.

Thurber needlegrass (*S. thurberiana*) is probably the least fire resistant needlegrass. Uresk et al (1976) found that an August wildfire reduced the basal area by 53% with a concurrent decrease in leaf length. In eastern Oregon, Thurber needlegrass was severely damaged by burning (Britton and Sneva, 1977). Plants burned in mid-May had 80% mortality and the basal area was reduced by 93%. In mid-June, mortality increased to 90% with a 93% reduction in basal area. Least damage resulted from October burns with no mortality and a 48% reduction in basal area. Wright and Klemmedson (1965) reported similar results for Thurber needlegrass.

Sedges

Response of sedges to burning is variable. Pechanec and Stewart (1944) list threadleaf sedge (*Carex filifolia*) as being severely damaged while Douglas sedge (*C. douglasii*) was classed as undamaged. This difference was reported to be due to the ability of Douglas sedge to initiate growth from basal buds. Twelve years after burning, Blaisdell (1953) reported sedges were producing more on light burns but less on moderate and heavy burns in one area while the opposite trend was found on another area. Threadleaf sedge was found to be producing on the average more on burned areas as compared to unburned, therefore initial damage by burning was not permanent. Douglas sedge was reduced in number of plants as a result of a wildfire in northeastern California (Countryman and Cornelius, 1957).

Squirreltail

Squirreltail (Sitanion hystrix) is one of the more fire resistant bunchgrasses, although some damage is apparent. In southern Idaho, Wright and Klemmedson (1965) observed no plant mortality as a result of burning. There was some reduction in basal area for plants burned in June but it was most apparent (15% reduction) in July for both large and small plants. In August, only the large plants responded to hot burns with a 16% reduction in basal area. The greater overall damage in July was probably due to higher initial burn temperatures in the plant crown. Wright (1971) reported that burning generally harmed squirreltail most during May and somewhat less thereafter to increase the first year after wildfire in northeastern California but decreased by the third year (Countryman and Cornelius, 1957).

Burning squirreltail plants in a drouth year in eastern Oregon resulted in 30% mortality in mid-May (Britton and Sneva, 1977). No mortality was recorded for mid-June or October burns. The mid-May burns reduced basal area by 73% while the October burn reductions were 48%.

In west-central Utah, squirreltail cover was found to increase during the first 5 to 6 years after burning (Barney and Frischknecht, 1974). This increase was stable for up to 40 years. Often squirreltail plants are very small and will increase in size rapidly after a burn. The larger plants, however, would be slightly harmed (Wright, 1971; Britton and Sneva, 1977).

Wheatgrasses

Fall burning of crested wheatgrass (Agropyron desertorum) results in only small changes in the stand. Density of plants should remain unchanged (Kay, 1960), although yield may be reduced during the first growing season after burning (Lodge, 1960). After growth initiation, spring burning can reduce yield for 2 years (Lodge, 1960). Crested wheatgrass seedlings are considered somewhat fireproof as many observers report that wildfires move only a few feet into a seeding.

Bluebunch wheatgrass (A. spicatum) is slightly affected by burning. Twelve years after burning, Blaisdell (1953) found a 1.7-fold increase in yield compared to unburned controls. After 30 years, yield of bluebunch wheatgrass on the same area was slightly below the controls (Harniss and Murray, 1973). Cover of bluebunch wheatgrass remained uniform in west-central Utah for 40 years after burning before the juniper overstory caused a decline (Barney and Frischknecht, 1974).

The negative effects of burning bluebunch wheatgrass are usually evident only in the first year after burning. Uresk et al (1976) measured decreases in leaf lengths and basal area, but an increase in yield 1 year after burning in eastern Washington. These results are similar to the 29% reduction in basal area and 1% mortality observed in the same region by Conrad and Poulton (1966). In eastern Oregon during mid-May, burning decreased the basal area by 78% with a 50% mortality. When plants were burned during the fall, there was no mortality but a reduction in basal area of 47% compared to preburn measurements of the same plants (Britton and Sneva, 1977). These effects were measured during an extremely dry year which magnifies the effects of burning (Wright, 1974). Bluebunch wheatgrass will usually return to preburn production in 1 to 3 years

(Blaisdell, 1953; Moomaw, 1957; Daubenmire, 1963; Conrad and Poulton, 1966; Uresk et al, 1976).

Other wheatgrasses respond somewhere between crested wheatgrass and blue-bunch wheatgrass with the exception of the rhizomatous wheatgrasses. Thickspike wheatgrass (A. dasystachyum) exhibits virtually no change 1 year after burning and after 12 years was producing about twice as much as unburned controls (Blaisdell, 1953). It appeared that the more intense the burn the greater the response. In northeastern California, a mixed wheatgrass stand was burned in the fall of the third growing season (Kay, 1960). The following summer, a 25% increase in stocking was measured and was primarily due to rhizomes of intermediate wheatgrass (A. intermedium) and pubescent wheatgrass (A. trichophorum). Tall wheatgrass (A. elongatum) remained unchanged. In North Dakota, western wheatgrass (A. smithii) was unchanged in frequency regardless of site or soil (Dix, 1960).

RESPONSE OF FORBS TO BURNING

Forbs generally respond better to burning than do grasses. Where plant communities have large proportions of forbs in the herbaceous component, burning may provide the best manipulation technique. Fall burning does not harm most forbs because they are often dry and disintegrated by this time. Pechanec and Stewart (1944) classified forbs according to their susceptibility to fire.

Due to lack of research evidence on individual forb species, no attempt will be made to review each species mentioned in the literature. Instead each article mentioning forbs will be abstracted.

Probably the best research treatment of forbs is from the prescribed burns conducted in Clark and Fremont counties on the upper Snake River plains of Idaho. This work is presented in a series of three articles by Pechanec et al (1954); Blaisdell (1953); and Harniss and Murray (1973). Pechanec et al (1954) observed that the rapidity of increase by the lightly damaged or undamaged species depended largely on whether the plant spreads by rootstocks. Those that do not, even though undamaged, increase slowly after burning. These include some of the more palatable species such as arrowleaf balsamroot (Balsamorhiza sagittata) and tailcup lupine (Lupinus caudatus). Despite a ready recovery from burning, any increase in number of plants must await seed production.

Plant species spreading by rootstocks or root shoots are least harmed and spread most rapidly after burning. These species include western yarrow (Achillea lanulosa), purpledaisy fleabane (Erigeron corymbosus), longleaf phlox (Phlox longifolia), flaxleaf plainsmustard (Sisymbrium linifolium), lambstongue groundsel (Senecio integerrimus), orange arnica (Arnica fulgens), and common comandra (Commandra umbellata). Such species as western yarrow, longleaf phlox, and purpledaisy fleabane doubled in production within 3 to 4 years.

Approximately 12 years after the burns in Clark and Fremont counties, Blaisdell (1953) re-evaluated the vegetation response. He found that total forb production was considerably higher on all burn intensities as compared to unburned areas in Fremont county. For unburned, light burn, moderate burn, and heavy burn areas, forb production in pounds per acre was 127, 191, 237, and 170, respectively. Of the species mainly responsible for the higher yield of forbs on burned areas, western yarrow, aster (Aster sp.), fleabane, and goldenrods (Solidago sp.) are rhizomatous perennials. Littleleaf pussytoes (Antennaria microphylla), a woody stemmed forb of low forage value, and sticky geranium (Geranium viscosissimum), a perennial rated fair forage, also contributed to the higher yield, especially on light and moderate burns. On the other hand, yield of knotweed (Polygonum douglasii), an undesirable annual, was greatest on the heavy burn. The lower yield of plumeweed (Cordylanthus ramosus) on the burned areas as compared to unburned did approach statistical significance.

The 1934 inventories showed a marked increase in total production of forbs on burned areas in relation to that on the unburned. This trend continued through the third year, especially on burns of light and moderate intensity. Although much of these early increases had disappeared by 1948, differences were still significant for light and moderate burns.

Rhizomatous species on all burn intensities showed relative increases the first year after burning, but subsequent trends were variable. On the other hand, woody forbs (pussytoes and erigonum (Erigonum caespitosum and E. heracleoides)), decreased markedly, roughly proportionate to burn intensity, and then increased. Annuals, primarily gayophytum (Gayophytum diffusum), knotweed, plumeweed, and goosefoot (Chenopodium sp.), made enormous relative increases in 1934, roughly in proportion to burn intensity. Portions of these relative increases persisted through 1936, but had disappeared by 1948 on all but the heavy burn. The persistence of annuals on the heavy burn was shown by actual yield of knotweed, 26 pounds on the heavy burn as compared to 7 on the unburned. Other perennial forbs generally showed an initial but temporary increase after burning.

After 12 years, only the heavy burn in Clark county supported a significantly higher yield of forbs compared to the unburned area. It appeared that fleabane and phlox (both rhizomatous species) on burns of all intensities and lupines on the heavy burn were producing more than on the unburned. Apparently the effect of burning on the other forbs was negligible after 12 years.

In contrast with Fremont county, inventories of Clark county plots the year after burning showed a decrease in total forb production on burned areas in relation to the unburned. By the third year considerable increases in relative yield were evident, but most of these early effects disappeared during the next 9 years. As in Fremont county, rhizomatous forbs generally increased the first year, but woody species, erigonum, and pussytoes decreased markedly on all burns. Rhizomatous species continued to increase through the third year then decreased. After the initial relative decreases, woody species increased throughout the study period and regained much of their original losses. With the exception of plumeweed, annuals were present only in very small amounts. Other perennial forbs increased the first year on burns of all intensities, but trends in following years were not well defined.

By 1966, Harniss and Murray (1973) found little difference in forb production on burned and unburned plots. Although individual species were not mentioned, perennial forbs accounted for the bulk of the production.

Abandoned fields on the Snake River plains dominated by cheatgrass were burned during the early 1930's (Piemeisel, 1938). The first year after burning, the major portion of the vegetation was tumbledustard and Russian thistle with some flaxweed tansymustard (Descurainia sophia). It took 2 to 3 years for the fields to again be dominated by cheatgrass. Near Dubois, Idaho, Mueggler and Blaisdell (1958) reported an increase in forb production after burning. Those species most benefited included timber poisonvetch (Astragalus convallarius), purpledaisy fleabane, and lupine. Forbs that were injured include littleleaf pussytoes and matroot penstemon (Penstemon radicosus).

In western North Dakota, Dix (1960) found that wild lettuce (Lactuca pulchella) decreased about 20% with the most dramatic decrease (63%) on loamy fine sand. Red globemallow (Sphaeralcea coccinea) increased when present in the vegetation.

Robocker et al (1965) found on a sandy soil in eastern Washington that burning decreased most forbs. Burning appeared to have reduced stands of tumbledustard, tansymustard (Descurainia pinnata), and whitlow-wart (Draba verna).

In west-central Utah, Barney and Frischknecht (1974) sampled burns ranging in age from 3 to over 100 years. The most abundant forbs during the first stages of succession were pale alyssum (Alyssum alyssoides), flaxweed tansymustard, sunflower (Helianthus annuus), coyote tobacco (Nicotiana attenuata), and Russian thistle. Since these forbs were abundant on recent burns, it can be assumed that they were not seriously damaged by burning.

Yarrow was found to decrease the first 2 years after burning in northeastern California (Countryman and Cornelius, 1957). However, by the fifth year there was a 7.5-fold increase in crown area.

In eastern Oregon, tailcup lupine changed slightly in cover from an average of 15% to over 16% 1 year after fall burning (Britton and Sneva, 1977). The burns were in a dry year followed by a drier year. Hammersmark (1977) observed in southern Oregon that astragalus, arrowleaf balsamroot, tapertip hawksbeard (Crepis acuminata), tailcup lupine, globemallow, and foothill deathcamas (Zigadenus paniculatus) were not damaged by wildfire. In Nevada, Wagner (1977) measured a 3-fold increase in frequency of longleaf phlox with no reduction in wild onion, astragalus, tapertip hawksbeard, lupines, globemallow, and foothill deathcamas as a result of wildfire.

RESPONSE OF SHRUBS TO BURNING

Bitterbrush

The specific effect of fire on bitterbrush depends on the species and location (Nord, 1965). For example, abundant resprouting of antelope bitterbrush (*Purshia tridentata*) occurs in eastern Idaho (Blaisdell, 1953; Blaisdell and Mueggler, 1956), limited resprouting occurs in central and northern Utah (Blaisdell and Mueggler, 1956) and very little resprouting occurs in Oregon and California (Nord, 1965). Billings (1952) reports that fire eradicates bitterbrush in the western Great Basin because it rarely root-sprouts in that region, and seeds of bitterbrush do not disseminate from their source. Klebenow et al (1976) report that bitterbrush resprouts in Nevada generally died the year following burning. However, good production from seed resulted from the burn. The natural frequency of fire in areas that contain antelope bitterbrush is probably not more than 41 to 50 years, if that often.

Generally speaking, antelope bitterbrush is a weak sprouter and living plants are severely damaged by fire (Blaisdell, 1953; Pechanec et al, 1954; Countryman and Cornelius, 1957; Nord, 1965). For antelope bitterbrush to resprout regularly in areas such as southeastern Idaho, the soil must be wet at the time of the burn or shortly after the burn (Blaisdell, 1953; Blaisdell and Mueggler, 1956; Nord, 1965). Otherwise, antelope bitterbrush seldom resprouts. If antelope bitterbrush plants do resprout, they will regain their original growth in 9 to 10 years (Blaisdell, 1953). For a burn in Idaho that was followed by some dry years, antelope bitterbrush was only producing 50 to 60% as much as the control 12 years after the burn (Blaisdell, 1953).

Ecotypic variation would normally be expected within a wide-ranging species like bitterbrush. Alderfer (1977) reports three ecotypes in northern California and Oregon, a high elevation decumbent form, and two columnar forms. Monsen (1977) has indicated three types occurring in Idaho, a low elevation decumbent form and two columnar forms, with one on granitic soils and the other on calcareous soils. In Utah, Plummer suggests that the decumbent and columnar forms represent at least two types.

The decumbent ecotype generally resprouts after fire or top removal. It is an aggressive pioneer species capable of revegetating highly disturbed areas after planting (Monsen and Christensen, 1975). The columnar form on granitic soils in Idaho will also generally resprout after fire or top removal, but resprouting seems to be dependent on fire intensity and soil moisture. The other ecotypes apparently are more severely damaged by fire.

The decumbent life form is easily planted from seed and is successfully used for rangeland and logging road rehabilitation, particularly on well drained, coarse textured soils (Monsen and Christensen, 1975). Since seeds must be cold treated and scarified (Young and Evans, 1976), the best time to burn for seed production is the fall (Monsen and Christensen, 1975). Abundant natural regeneration from seed caches following fall prescribed burning has been reported by Klebenow et al (1976). Seedlings from the low growing forms of antelope bitterbrush appear more competitive than do the upright forms (Monsen and Christensen, 1975), and germination is high (Holmgren, 1954). However, seedlings cannot compete with annual grasses during the first growing season (Holmgren, 1956).

Desert bitterbrush (*Purshia glandulosa*) usually resprouts after fire (Nord, 1965). This species is closely related to antelope bitterbrush and the two interbreed (Monsen and Christensen, 1975) when their populations overlap. The amount of genetic variation induced by interbreeding significantly affects both palatability and resprouting in antelope bitterbrush.

Tentative conclusions deduced from the data presented on antelope bitterbrush follows: (1) High intensity wildfires during mid-summer do the most damage to bitterbrush when the burning is followed by summer drought; under these conditions, most of the bitterbrush is killed. Cool spring burns in the decumbent ecotype(s) of bitterbrush result in low mortality and high resprouting; however, few seedlings establish in the burned area. Fall prescribed burns result in higher mortality than spring burns, but lower mortality than summer burns. If fall prescribed burns are conducted with favorable soil moisture conditions at the time of the burn or just after the burn, resprouting and layering occur in the decumbent ecotype. Reproduction from seed is highest following a fall burn. (2) Fire harms the columnar ecotypes more than it does the decumbent ecotypes. Cool fall fires are more important for the survival of antelope bitterbrush in the upright growth forms than in the low growth life forms. (3) Fire harms bitterbrush more on fine textured and calcareous soils than on coarse textured and well drained soils. Specific habitat and soils data are not available.

Cliffrose

Two varieties of cliffrose are recognized (*Cowania mexicana* var. *mexicana* and var. *stansburiana*). Apparently, Stansbury's cliffrose is a strong sprouter and an aggressive pioneer species whereas the *mexicana* cliffrose is a weak sprouter and not so aggressive. Research on *Cowania mexicana* shows that it is generally killed by fire (Pechanec et al, 1954; Vallentine, 1971; Klebenow et al, 1976). Like desert bitterbrush, cliffrose interbreeds with antelope bitterbrush (Nord, 1965; Sanderson, 1969).

Sagebrush

Big-sagebrush (*Artemisia tridentata*) is easily killed by fire (Blaisdell, 1953; Pechanec et al, 1954; Ralphs et al, 1975). Blaisdell (1953) reports that big-sagebrush does not resprout in southeastern Idaho, and repeated burning can almost completely eliminate sagebrush from a site (Pickford, 1932). However, without repeated fires, sagebrush will invade the burned area via seeding. Sagebrush begins to reoccupy the area during the first year after the burn. Working at Dubois, Idaho, Blaisdell (1953) found that sagebrush in burned areas (12 years after the burn) was 10% of that in unburned areas, but had reached unburned levels in 30 years (Harniss and Murray, 1973). Some areas recover more quickly if seed and moisture are available after burning (Pechanec et al, 1954; Johnson and Payne, 1968).

Mountain sagebrush (*A. tridentata* subsp. *vaseyana*) recovers more quickly than other subspecies of big-sagebrush perhaps because it occupies more mesic sites and growing conditions are more favorable for seed production and reestablishment (Hironaka, 1977). Winward and Tisdale (1977) indicated that it shows a stronger tendency to increase in plant density and foliage cover in stands where the herbaceous vegetation is disturbed than basin big sagebrush (*A. tridentata* subsp. *tridentata*) or Wyoming big sagebrush (*A. tridentata* subsp. *wyomingensis*). Basin big-sagebrush normally occupies lowland plains and valleys.

on basic soils whereas Wyoming big sagebrush occupies drier valley and foothill sites (Plummer, 1977). Though seed production is variable, depending on soil moisture conditions, germination rates of all three subspecies of big-sagebrush are high enough in all years to exclude seed germination as a limiting factor to reinvasion (Harniss and McDonough, 1976).

High intensity wildfires leave few unburned plants and consume most seeds, which accounts for the variable density of reinvasion big sagebrush. Maximum spread of progeny from parent plants of big sagebrush is 42 feet (Frischknecht, 1962), so wind is evidently not a big factor in moving seed from adjacent unburned areas into burned areas. Normally, seeds of big sagebrush do not remain viable in the soil or litter for more than 3 to 5 years (Monsen, 1977).

Other important closely related species are the lower growing black sagebrush (*A. nova*), low sagebrush (*A. arbuscula*), silver sagebrush (*A. cana*), and three-tip sagebrush (*A. tripartita*). Fires rarely occur in the black and low sagebrush types. These shrubs grow in areas of shallow and droughty soils where production of herbaceous plants is often inadequate to support a fire. Black and low sagebrush can reproduce by seed after a fire but do not resprout. Three-tip sagebrush is a weak sprouter and silver sagebrush is a vigorous sprouter.

Rabbitbrush

Rabbitbrush (*Chrysothamnus* sp.), a common genera in the sagebrush-grass zone, is usually enhanced by fire (Cottam and Stewart, 1940; Blaisdell, 1953; Countryman and Cornelius, 1957; Chadwick and Dalke, 1965; Young and Evans, 1974). An exception to this general response are two observations by Robertson and Cords (1957) for rubber rabbitbrush (*Chrysothamnus nauseosus*). This species showed no recovery 2 years after a burn on September 3, 1942 near Mono Lake, California and after a burn on November 7, 1943 near McGill, Nevada. However, a burn on the latter area was repeated the following year on the same date and 95% of the plants resprouted. Generally, this is what we expect to happen, but obviously there are conditions under which rubber rabbitbrush can be killed. Evidently, the intensity of the fire is important since most of the sprouting after fire is epicormic (stem sprouting), not basal or root sprouting (Monsen, 1977).

Chrysothamnus puberulus, *C. bloomeri*, *C. lanceolatus*, and *C. viscidiflorus* all resprout vigorously and re-seed well on disturbed areas (Plummer, 1977). Seeds will carry long distances and growth of seedlings is rapid.

For living plants that resprout, production is reduced for 1 to 3 years after burning, then it increases dramatically (Blaisdell, 1953). On the U.S. Sheep Station near Dubois, Idaho, burning reduced production 59% the first year after burning (Blaisdell, 1953). Three years after burning, production doubled and was tripled at the end of 12 years. Similarly, Chadwick and Dalke (1965) found that the cover of *C. viscidiflorus* had increased 4 to 9 times on 8 to 18-year-old burns on sandy soils in northeastern Idaho. Production of *C. bloomeri* doubled 5 years after a burn in northern California (Countryman and Cornelius, 1957). In western Nevada, Young and Evans (1974) found that green rabbitbrush (*C. viscidiflorus* var. *viscidiflorus*) continued to dominate burns and reestablish itself periodically for 15 years. Communities 40 to 50 years old were dominated by big sagebrush and contained reduced populations of green rabbitbrush.

Broom Snakeweed

Broom snakeweed (Gutierrezia sarothrae) is a weak sprouting perennial that is severely damaged by fire (Pechanec et al, 1954; Wright, 1972). It may be completely removed from an area (Stanton, 1973). New plants tend to invade open areas rapidly, and the highest frequencies of broom snakeweed are found on 22-year-old burns (Barney and Frischknecht, 1974). Populations decline gradually for 50 years. On 100-year-old burns, populations are reduced to less than 10% (Barney and Frischknecht, 1974).

Horsebrush

Horsebrush (Tetradymia canescens) is a vigorous post-fire sprouter that also reproduces abundantly from seed. Species of horsebrush cause liver damage to sheep with symptoms of photosensitization developing into severe poisoning (Kingsbury, 1964). Fire may reduce horsebrush by 50% the first year after a burn, but the species doubles at the end of 3 years after a burn (Blaisdell, 1953). Twelve years after this same burn, horsebrush had increased 5-fold. Thirty years after the burn many plants become decadent and begin to die out (Harniss and Murray, 1973). If fire or chemicals are used to treat decadent growth, horsebrush will become overwhelmingly dominant.

In addition to spineless horsebrush (Tetradymia canescens), littleleaf horsebrush (T. glabrata) and catclaw or spiney horsebrush (T. spinosa) resprout after fire. However, littleleaf and catclaw horsebrush normally grow in drier sites in which there is not enough fuel to carry a fire (Hironaka, 1977). Hence, only spineless horsebrush is a potential problem following prescribed burning.

Gambel's Oak

In Colorado, fire stimulates suckering of Gambel's oak with a resultant thickening and merging of stands into continuous thickets (Brown, 1958). In Utah, McKell (1950) found that Gambel's oak grew rapidly the first two growing seasons (50% recovery) after burning, but it had only recovered 75% of its original cover in 18 years after the burn (Wright, 1972). The number of shoots increased after the fire and then they declined until they were equal on both burned and unburned areas 18 years after the burn (Wright, 1972). Oak tends to thin out and retreat when protected from fire (Brown, 1958).

Snowberry

After fire, common snowberry (Symphoricarpos albus) will resprout vigorously from both rhizomes and basal buds. Creeping snowberry (S. mollis) is found in moister habitats. It is a weak sprouter after fire because its rhizomes, which may develop in deep humus, are sometimes consumed or damaged in an intense fire (Stickney, 1977). Mountain snowberry (S. oreophilus) is found in drier habitats extending into sagebrush grass. It is a weak sprouter after fire. Pechanec et al (1954) and Blaisdell (1953) found that it decreased initially after burning although no further change was observed 12 years after burning.

Snowberry is capable of producing fire brand material. When snowberry is located near fire control lines, it should be red flagged as spot-fire potential.

Mountain-mahogany

True mountain-mahogany (Cercocarpus montanus) is a vigorous sprouter after being burned (Erdman, 1970; Vallentine, 1971). It is also highly palatable and of major importance in the western United States (Medin, 1960).

Curlleaf mountain-mahogany (C. ledifolius) is a weak sprouter after being burned, but many of the resprouts die during the following two or three seasons (Monsen, 1977). Curlleaf is a slow growing species, particularly as a seedling, but it can grow into a small tree (Dealy, 1975). The ability to resprout after pruning decreases as the age and size of the plant decreases (Ferguson and Basile, 1966; Ferguson, 1968). Few tree-like curlleaf mountain-mahogany plants resprout after fire (Monsen, 1977).

Rose

Several members of the rose family respond similarly to fire. Throughout their ranges serviceberry (Amelanchier alnifolia), oceanspray (Holodiscus discolor), ninebark (Physocarpus malvaceus), bittercherry (Prunus emarginata), little-wild rose (Rosa gymnocarpa), woods rose (Rosa woodsii), and shiny-leaf spiraea (Spiraea betulifolia), resprout from a root crown. They resprout in habitats of subalpine fir (Lyon, 1976), grand fir (Asherin, 1972), cedar-hemlock (Mueggler, 1965; Leege, 1968), Douglas-fir (Lyon, 1971), ponderosa pine (Daubenmire, 1968), oak-brush (McKell, 1950), and sagebrush (Neuenschwander, 1977). Vegetative reproduction following burning is the primary method of propagation. Reproduction from seed is rarely observed after a burn. When seedlings are observed in a burn, their rate of growth is slow compared to that of other species (Stickney, 1977).

Serviceberry

Serviceberry may be the most palatable browse species and the most fire sensitive within the rose family. At least two growth forms are recognized (Lonner, 1972) with several varieties. The driest variety, western serviceberry (Amelanchier alnifolia var. utahensis), is damaged by fire but it resprouts (Stanton, 1973; Wright, 1972). The more mesic variety, common serviceberry (A. alnifolia var. alnifolia), also resprouts and is not severely harmed. Based on observations in southern Idaho and in Utah, no mortality following wildfires has been recorded for Utah serviceberry (Monsen, 1977). Apparently western serviceberry, which is a long-lived species (Hemmer, 1971), can remain suppressed in a closed stand of conifers or juniper for a long period of time. Canopy removal from the resident trees will stimulate resprouting (Asherin, 1972; Lyon, 1971).

Ceanothus

Most seeds of Ceanothus can withstand high external temperatures and maintain germination capabilities (Biswell, 1974). Snowbrush (C. velutinus) and redstem ceanothus (C. sanguineus) seeds require heat scarification before they will germinate (Lyon, 1976). In addition, they resprout after fire. Sprouting may be considered an adaptation to recurring fires (Biswell, 1974) because of the rapid growth and recovery after fire. Thus, Ceanothus is well adapted to fire for two reasons: (1) Many of the shrubs resprout after fire; (2) seeds which are produced at an early age may lie dormant and viable in the duff and soil for extremely long periods of time, and are highly resistant to fire. Seedlings are usually abundant after fire.

In one study by Legee (1968) in which he compared spring burns to fall burns to rejuvenate redstem ceanothus, spring burns were found to stimulate more resprouts than fall burns, but few seedlings of redstem ceanothus were alive by the end of the second growing season after the burn. However, many seedlings of redstem ceanothus survived the fall burn. Legee's study findings, if applicable to other species of Ceanothus, may imply that spring burning could potentially harm the species that reproduce primarily by seed. Late summer or fall burning, however, would increase the numbers of young plants. Frequent fires could possibly remove Ceanothus species reproducing by seed from an area, or at least, favor plants that resprout.

Conclusion

The effect of fire on shrubs is variable, enhancing some species and damaging others. The state of the art on the effect of fire on shrubs of the drier forest and sagebrush-grass zones of the Intermountain Region, as presented, indicates that most of the data collected are superficial and, in many cases, inadequate. However, baseline data on response to fire is available for key species even though specific data is lacking.

Research should be undertaken on key shrubs to determine specific effects of fire. Survival and reproductive capabilities of the key shrub species, sub-species, and ecotypes need to be correlated with habitat type and/or soil type, soil moisture, season of burning, and fire intensity. In addition, proper grazing management for key species following the fire has not been determined.

In light of research needs, resource managers should document burns as to soil moisture (wet or dry), season of burn (date), fire intensity (hot vs cold), and habitat type.

RESPONSE OF PINYON AND JUNIPER TO BURNING

Pinyon and Juniper

The effect of fire on living pinyon and non-sprouting juniper trees depends largely upon the height of trees, herbaceous fuel, weather conditions, and season. In open pinyon-juniper stands with an understory of 700 to 1,000 lb/acre of fine fuel, Jameson (1962) and Dwyer and Pieper (1967) found that pinyon and juniper were easily killed by spring fires if less than 4 feet tall when air temperature was 70 to 74° F, relative humidity 20 to 40%, and wind speed is 10 to 20 mph. Lower air temperatures in January (49 to 54° F), relative humidity 44%, and wind of 6 to 8 mph caused a very spotty burn in which crown kill varied from 30 to 70% of trees 2 to 4 feet tall, but 70% of the trees died (Jameson, 1962). A wildfire in June with an air temperature of 97° F, wind 10 to 15 mph, and relative humidity 17 to 25% assured a 100% kill of all trees less than 4 feet tall, but was no more effective on taller trees than when air temperatures were 70 to 74° F (Jameson, 1962).

Trees greater than 4 feet tall in open pinyon-juniper stands are difficult to kill unless you have excess accumulations of fine fuel beneath the trees. On the wildfire studied by Dwyer and Pieper (1967), only 24% of the pinyon and 13.5% of the juniper which exceed 4 feet died. Jameson (1962) found that most juniper over 4 feet tall only had a 30 to 40% crown kill, unless tumbleweeds had accumulated at the base of the trees. Then 60 to 90% of the crowns were killed, particularly for trees 8 to 10 feet tall. East of the pinyon-juniper zone in Texas, juniper trees up to 12 feet tall were easily killed when fine fuel was 2,000 lb/acre or higher (Wink and Wright, 1973).

Trees in closed stands (no grass or shrubs in the understory) of pinyon-juniper are difficult to kill because fires won't carry easily (Arnold et al, 1964; Blackburn and Bruner, 1975). Dense stands (495 to 988 trees/acre) in 14 to 18-inch rainfall areas with a mixture of pinyon and juniper can be burned on hot days, but pure stands of juniper are almost impossible to burn (Blackburn and Bruner, 1975). A number of people in the Great Basin area speculate that it would require winds over 35 mph to burn pure stands of juniper. Thus, many attempts to burn such stands have failed (Arnold et al, 1964; Aro, 1971). As the proportion of pinyon to juniper increases and the density increases, the stands are easier to burn (Truesdell, 1969; Blackburn and Bruner, 1975). Such areas are usually burned by clearing an area 20 to 125 feet wide and pushing a windrow against the green trees on the windward side and letting the material cure for 60 to 90 days. Then in June or July, burns are conducted when temperatures vary from 80 to 95° F, relative humidity is 4 to 8%, and winds exceed 8 mph (Truesdell, 1969; Blackburn and Bruner, 1975). These burns have been conducted on mesas or next to the Grand Canyon where firebrands are not a problem.

A mixture of sagebrush and pinyon-juniper is common throughout the Great Basin, and it is feasible to burn and kill large pinyon and juniper trees in these communities (Bruner and Klebenow, 1978). To get a fire to carry, Bruner and Klebenow (1978) have proposed the "White Pine County Formula" where,

Index = Maximum wind (mph) + Shrub and Tree Cover (%) + Air Temperature (°F).

If the index is 110 or higher, a fire will carry and will kill the large pinyon and juniper trees. If the index is above 130, it is too dangerous to burn. Most of the work by Bruner and Klebenow has been done in pinyon-juniper stands

with 45 to 60% of shrub and tree cover and burned when air temperature was 60 to 75° F, relative humidity was below 25%, and maximum wind speed was 5 to 25 mph.

Alligator juniper and redberry juniper are the only sprouting species. Smith et al (1975), found that if the tops of redberry juniper trees were removed before they reached 12 years of age, 99% mortality could be expected. Older trees were not studied. This data implies that if subjected to fire every 10 years or so, sprouting species of juniper may have a difficult time invading grasslands. Schroeder (1956) found that about 40% of alligator juniper trees less than 15 feet tall could be killed by burning individual plants (quoted by Blackburn and Bruner, 1975).

Table 1. Relative Response of Cold Desert Grass and Grass-like Species to Burning.

Severely damaged	Slightly damaged	Undamaged
Idaho fescue	Bluebunch wheatgrass	Cheatgrass
Needle-and-thread	Big bluegrass	Crested wheatgrass
Threadleaf sedge	Columbia needlegrass	Douglas sedge
Thurber needlegrass	Cusick bluegrass	Intermediate wheatgrass
	Indian ricegrass	Plains reedgrass
	Nevada bluegrass	Prairie junegrass
	Squirreltail	Pubescent wheatgrass
	Western needlegrass	Riparian wheatgrass
		Sandberg bluegrass
		Tall wheatgrass
		Thickspike wheatgrass
		Western wheatgrass

Table 2. Relative Response of Cold Desert Forbs to Fall Burning.

Severely damaged	Slightly damaged	Undamaged
Hairy fleabane	Astragalus	Arrowleaf balsamroot
Hoary phlox	Matroot	Common camandra
Littleleaf pussytoes	Munro globemallow	Common sunflower
Low pussytoes	Northwestern paintbrush	Coyote tobacco
Mat eriogonum	Pinnate tansymustard	Douglas knotweed
Uinta sandwort	Plumeweed	Flaxleaf plainmustard
Wyeth eriogonum	Red globemallow	Flixweed tansymustard
	Sticky geranium	Foothill deathcamas
	Tatcup lupine	Gayophytum
	Tapertip hawksbeard	Goldenrod
	Tongueleaf violet	Goosefoot
	Tumblemustard	Lambstongue groundsel
	Wavyleaf thistle	Longleaf phlox
	Whitlow-wart	Orange arnica
	Wild lettuce	Pale alyssum
		Purpledaisy fleabane
		Russian thistle
		Velvet lupine
		Western yarrow
		Wild onion

Table 3. Summary of the Effect of Fire on Major Shrub Species in the Drier Forest and Sagebrush Grass Zones of the Intermountain Region.

Species	Sprouting Ability	Response to Fire	Recovery Time	Remarks
Antelope bitterbrush	Weak sprouter	Severely damaged by summer and fall burns	30-40 years	Effect determined by growth form; decumbent form sprouts vigorously, columnar form is a weak sprouter. If plants sprout, they will recover in 9 to 10 years. Spring burns enhance sprouting but fall burns are best for reproduction from seed. Burn when soil is wet.
Desert bitterbrush	Sprouter	Unharmed		
Cliffrose	Weak to non-sprouter	Usually killed by fire		
Big sagebrush	Non-sprouter	Severely harmed	30 years	Good seed crop before burning hastens recovery. Effective control requires burning before seed-set and periodic burns. May use black and low sage as fuel breaks. Subspecies of big-sagebrush appear to be important relative to response to burning.
Black-sagebrush	Non-sprouter	Rarely burned		
Low sagebrush	Non-sprouter	Rarely burned		
Silver sagebrush	Sprouter	Slightly harmed		
Three-tip sagebrush	Weak sprouter	Harmed	30 years	
Rubber rabbitbrush	Vigorous sprouter	Enhanced	20-25 years	May be killed if burned after heavy grazing or burned in early summer.
Green rabbitbrush	Vigorous sprouter	Enhanced	20-25 years	
Broom snakeweed	Weak sprouter	Severely harmed	20-25 years	Rapid recovery.
Horsebrush	Vigorous sprouter	Enhanced	30-35 years	Toxic, increases 5-fold within 12 years.
Gambel's oak	Vigorous sprouter	Enhanced	30-40 years	
Common snowberry	Vigorous sprouter	Unharmed	10 years	Enhanced by cool fires but harmed by hot fires.
Mountain snowberry	Sprouter	Slightly harmed	15 years	

Species	Sprouting Ability	Response to Fire	Recovery Time	Remarks
Mountain mahogany	Sprouter	Slightly harmed		More information is needed.
Western mahogany	Sprouter	Slightly harmed		
Curleaf mahogany	Sprouter	Moderately harmed		
Servicberry	Sprouter	Slightly harmed	30-50 years	Highly adapted to fire; soil moist at the time of the burn is important. Usually poor reproduction from seed.
Ocean-spray	Sprouter	Enhanced	20-30 years	
Hinebark	Sprouter	Enhanced	20-30 years	
Bittercherry	Sprouter	Unharmed	30-40 years	
Rose	Sprouter	Enhanced	15-30 years	
Spiraea	Sprouter	Unharmed	20-30 years	
Coanotus				
Non-sprouting group	Non-sprouters	Harmed by spring fires		
Sprouting group	Vigorous sprouters	Unharmed to enhanced		Seedlings are enhanced with fall burns.

Chapter VI

FIRE USE PLAN

by William L. Baker

Introduction

The purpose of this chapter is to present a fire use plan and report format that is consistent with both the philosophy and the activity related concepts of fire management. Acceptance of the proposed format would also serve the purpose of providing a standard terminology. For example, the terms fire prescription and burning plan are often used as synonyms. In the suggested format these terms have very specific and different meanings. This chapter lists the elements that should be considered when planning fire use. It does not tell how detailed the information relating to these elements needs to be. The required resolution and precision of needed information should be specified in prescribed fire guidelines. These guidelines can be written for local or regional areas or for individual vegetative types. The fire use planning format suggested here can be used as an outline for the organization and content of such prescribed fire guides.

Fire Use Planning--

From a fire management perspective, a successful prescribed fire is one that is executed safely, burns under control, accomplishes the prescribed treatment, and attains the land and resource management objectives for the area involved. Successful prescribed burning requires planning. Such planning should be based on the following factors:

1. Physical and biological characteristics of the site to be treated.
2. Land and resource management objectives for the site to be treated.
3. Known relationships between pre-burn environmental factors, expected fire behavior, and probable fire effects.
4. The existing art and science of applying fire to a site.
5. Previous experience from similar treatments on similar sites.

The proposed fire use plan is designed to direct the prescribed fire planner through the above factors in a logical sequence. The proposed report is designed to provide written record of actual prescribed burning experience that the planner can use when writing subsequent plans. The actual form of the resultant plan is left to the judgment of the planner or to the needs of his employer. Some prefer fill-in-the-blank type plans while others favor narrative type plans that vary in composition according to the complexity of the planned fire. The primary concerns here are the thought process involved in planning fire use and the technical validity of the plan produced. One final point before considering the proposed format: It is assumed the decision to use fire has already been made. It is further assumed the decision to burn is compatible with land and resource management objectives for the area and these objectives are defensible from an ecological standpoint.

The Fire Use Plan and Report--

The fire use plan and report format is in four parts. The first part deals with the planned fire treatment and the site to be treated. The prescribed fire planner is asked to describe the biological and physical characteristics of the site and to define the treatment objectives in terms of land and resource management objectives. The planner is also asked to identify all constraints that bear upon how prescribed fire can be applied to the area.

The information assembled in Part 1 is used to write the fire prescription, which is Part 2 of the proposed format. The first step in writing a fire prescription is to further define the treatment objectives in terms of the type and amount of work the fire must do. This is a critical task in the planning process. How well the fire accomplishes the desired work becomes the measure by which success or failure of the prescribed fire will be judged. Once the fire's work has been specified, the planner must draw upon existing knowledge of fire behavior and fire effects to determine (1) the type of fire behavior desired, (2) the environmental conditions under which the fire is likely to behave as desired, and (3) the burning techniques that must be used to get the fire to behave as desired under these environmental conditions.

The burning plan, Part 3 of the proposed format, is based upon the fire prescription. The burning plan is the action plan, or project work plan, for a prescribed fire. It translates the fire prescription into on-the-ground tasks that must be performed before, during, and after the actual fire. For each identified task, the plan should tell when and how it will be done and who will do it. The needed equipment and supplies are listed and the cost of the project is determined. A properly prepared burning plan becomes the only document needed by the people responsible for conducting the planned prescribed fire.

A standard EAR must be written for each burning plan under procedures set out in the BLM manual.

Part 4 of the report is designed to evaluate the plan in terms of the fire and its effects. The purpose of this evaluation is to provide valuable information for future fire use planning efforts. Too often such information is lost or only partially used by prescribed fire planners. Prescribed fire planners should keep a file of those reports, indexed appropriately for fast retrieval, and use them as a tool for fine-tuning subsequent fire prescriptions and burning plans. Fire information systems such as FIREBASE (Taylor and Eckels, 1977) might be used to store and retrieve such information.

An expanded outline of the proposed fire use plan and report format follows:

Part 1 - Treatment Area And Objectives

Purpose of Plan - State briefly and in general terms the type of treatment planned and its purpose.

For example:

--prescribed broadcast fire for hazard reduction and site preparation on a 35-acre clearcut unit containing larch/fir logging slash.

--prescribed broadcast fire for elk winter range improvement on a 500-acre low elevation mountain shrubland.

--prescribed broadcast fire for rejuvenation of 350 acres of little bluestem grassland.

The only purpose of this statement is to identify the type of activity being planned. Such a statement would logically follow the decision to use fire, which has already been made.

Treatment Area - Identify and describe the physical and biological characteristics of the area to be treated. Use maps, graphs, tables, etc., to show:

--size of area

--location

--elevation

--landforms (slope and aspect)

--soil types (erodibility, susceptibility to damage)

--vegetation (species, cover types, habitat types)

--down and dead fuels (amount, size class distribution, depth, continuity, etc.)

--climate and weather patterns (seasonal averages, probability of occurrence of different weather patterns, etc.)

--wildlife and wildlife habitats

Information on the above items often exists in ready to use form in land management plans, environmental statements and reports, resource management plans, and summaries of land and resource inventories.

Land Management Objectives - Summarize, very briefly, the land and resource management objectives and management guidance for the area to be treated. Refer to appropriate land management plans, resource management plans, silvicultural prescriptions, fire management plans, and other sources. For example:

Management Objectives--The management objectives for the lands within this management unit are to (1) protect the aquatic environment by maintaining

water quality for on and offsite use, (2) maintain the visual quality of the unit as reviewed from the major travel routes, and (3) manage the timber resource to maintain a healthy, productive forest within constraints imposed by watershed and visual concerns.

Management Guidance--Slash disposal will be complete enough to provide for free movement of wildlife through the management unit. Generally this means that slash concentrations more than 1-1/2 feet deep must be eliminated.

Treatment Constraints - Identify and define all constraints that bear upon how treatment can be applied. Consider:

- environmental constraints (air quality, water quality, accelerated erosion)
- multiple use constraints (protection of other uses, resource management trade-offs)
- economic constraints (maximum cost/acre)
- operational constraints (access, terrain, manpower, etc.)
- administrative constraints (agency policy, rules, etc.)
- legal constraints (State fire laws, forest practice acts, etc.)

Constraints are usually identified in the land management plan for the area to be treated. Other sources are agency rules, regulations, and policy; State and Federal laws; production rates and operational capabilities of men and machines; and project budgets.

Treatment Objectives - State in terms of land or resource management objectives referred to above and any constraints listed in the previous section. For example:

- reduce potential rate-of-spread to "low," provide for free movement by wildlife, regenerate area naturally with 1,000 western larch seedlings per acre.
- increase the amount of redstem ceonothus on the area, rejuvenate decadent shrubs to make them more available and palatable for elk and set back conifer encroachment.

Treatment Alternatives - Identify acceptable alternatives to the use of fire, if this was not done preceding the decision to use fire. State why they were not chosen.

This information can be important under certain circumstances whereby the manager must set priorities for burning because of time or manpower constraints. For example, if a shorter than expected prescribed burning season develops due to persistence of adverse summer burning conditions into the fall. In such a situation, efforts can be concentrated on burning those areas for which no acceptable non-fire alternative exists.

Part 2 - Fire Prescription

Treatment Specifications -

Desired Accomplishment--State, in precise terms, the work the fire needs to do, i.e.:

- inches or percent of duff to be removed
- amount or percent of fuels to be reduced by size class
- amount or percent of mineral soils to be exposed
- vegetation to be killed or otherwise treated by species

Desired Fire Behavior--Define the kind of fire needed to accomplish desired work while complying with any treatment constraints listed.

- rate-of-spread (fast or slow--specify acceptable range)
- fire intensity (hot or cool--specify acceptable range)
- flame height (especially if burning under a timber stand)
- flame length

To obtain this information, use prescribed fire guidelines, fire models, fire effects literature, consultation with experts, etc.

Required Environmental Conditions--Define the conditions, or range of conditions, necessary to obtain the desired fire behavior and effects. Use prescribed fire guidelines, fire models, consultation with experts, etc., consider:

- fuel moistures
- duff moisture
- windspeed and direction
- soil moisture
- temperature
- relative humidity
- physiological condition of vegetation (cured, dormant, etc.)

Treatment Strategy - Describe the sequence of events needed to achieve the treatment objectives and identify the tasks necessary for success.

- preburn tasks (slashing, snag felling, fireline construction, etc.)
- ignition technique (strip headfire, center fire, etc.)

--ignition methods (remote, drip torch, grenades, etc.)

--firing pattern or sequence

Pre-Burn Monitoring - Briefly describe how the area will be monitored to decide when conditions, specified above, are correct for burning. Indicate the measurements to be taken, where they will be taken, and the precision needed. Consider the need for fuels inventory, fuel and duff moisture measurements, weather measurements, etc.

Evaluation - Briefly describe how the treatment area will be evaluated to determine if treatment objectives, specified above, were met. Specify measurements to be taken during the fire to evaluate fire behavior and measurements to be taken after the fire to evaluate fire effects.

Part 3 - Burning Plan

Preparation for Burning - For each preburn task identified in the prescription, specify:

- what will be done
- when it will be done
- how it will be done
- who will do it
- equipment and supplies needed
- cost

Pre-Burn Monitoring - For each monitoring task identified in the prescription, specify:

- what will be done
- when it will be done
- how it will be done
- who will do it
- equipment and supplies needed
- cost

Ignition - On a map of the area to be burned, indicate ignition plan. Show sequence of ignition, placement of ignition crew, kind and location of ignition devices, etc., specify:

- what will be done
- when it will be done
- how it will be done
- who will do it
- equipment and supplies needed
- cost

Holding - Indicate on a map of the burn area placement of men and equipment for holding fire in planned area. Indicate how escapes will be dealt with, specify:

- what will be done
- when it will be done

- how it will be done
- who will do it
- equipment and supplies needed
- cost

Mop-up - Describe plans for mop-up and/or patrol after the fire has been conducted. Specify:

- what will be done
- when it will be done
- how it will be done
- who will do it
- equipment and supplies needed
- cost

Evaluation - For each evaluation task listed in the prescription, specify:

- what will be done
- when it will be done
- how it will be done
- who will do it
- equipment and supplies needed
- cost

Cost Summary - Summarize planned costs for manpower, equipment, and supplies.

Part 4 - Report

Accomplishment - State in precise terms the actual accomplishment of the fire. For example, 3 inches of duff removed; 20% of area bare to mineral soil. Relate this to the desired accomplishment listed in the fire prescription.

Timing of fire effects evaluation is important. Some effects are apparent immediately after the fire and should be evaluated within a week. Other effects might not be apparent until the start of the subsequent growing season. In such situations, the report should be revised to include the longer-term effects after they have been evaluated.

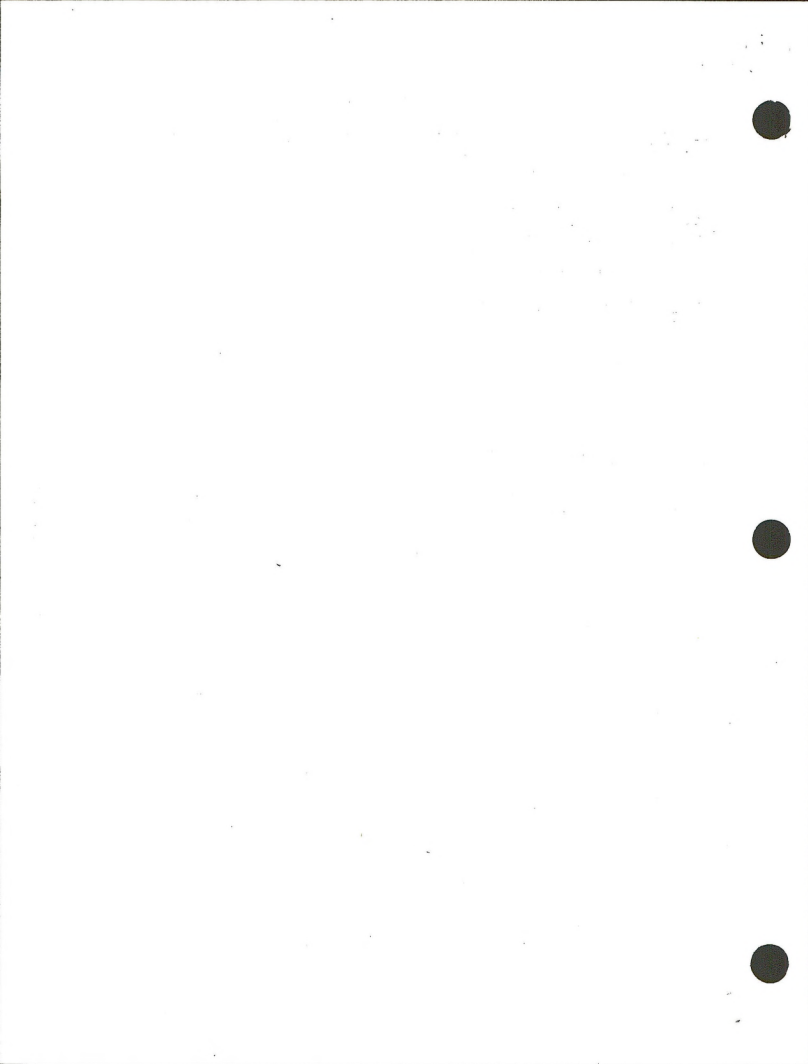
Fire Behavior - State the actual fire behavior that occurred. Relate this to desired fire behavior described in the fire prescription. Quantify, if possible.

Environmental Conditions - State the actual fuel moisture, weather conditions, and other designated environmental factors that preceded the fire and that occurred during the fire. Relate to those specified in the fire prescription.

Cost - State actual costs incurred. Explain any differences from estimated costs.

Observations and Recommendations - Summarize significant aspects of the fire in relation to expectations. Relate what actually happened to what was expected to happen. Indicate knowledge gained that should be considered when planning subsequent prescribed fires. For example (Norum, 1975):

Experience gained during this fire indicates a need to modify the ignition procedure for future hazard reduction burns in this fuel type. Because of the concentrated and discontinuous nature of the fuels, fires ignited across the lower edge of a plot often burned vigorously until a fuel discontinuity was reached, whereupon the fire went out. The result was a very ragged burn with hazardous fuel left in the center of the unit. Control and containment difficulties were experienced when ground fuels were sufficiently dry to carry fire between concentrations. Crown fires began to increase in frequency, and spotting outside of the prescribed area required alert patrol and vigorous suppression. Based on the results of this experience, I suggest ignition of strips of fuel across the slope, beginning at the upslope perimeter and progressing to the bottom of the plot. Permit each strip of ignited fuel to burn until the level of maximum intensity passes, then ignite the next downslope and adjacent strip. This procedure should assure ignition of all fuels and minimize control problems.



Chapter VII

PRESCRIPTION GUIDES

by Henry A. Wright

Sagebrush-Grass Communities

Big Sagebrush and Grass

Sagebrush is difficult to burn unless there is at least 600 to 700 lb/acre of herbaceous fuel (Beardall and Sylvester, 1976). Moreover, burning should not be considered as a management tool unless the cover of big sagebrush exceeds 30% (Pechanec et al, 1954). After the decision to burn has been made, try to avoid burning immediately after heavy seed crops for the sagebrush can reoccupy the burned area rapidly during years with good moisture (Pechanec et al, 1954; Johnson and Payne, 1968). Early spring or later summer (August) burns may be the most preferable (Blackburn and Bruner, 1975; Beardall and Sylvester, 1976). Good soil moisture down to 12 or 18 inches should be present before burning.

Various procedures have been used to conduct prescribed fire in sagebrush-grass communities. Pechanec et al (1954) plowed a single 8-foot fireline completely around an area in southeastern Idaho. Then immediately adjacent to the fireline on the downwind side, they plowed another line with the burn pushed to the center of the plowed area. This burn acted as a buffer for firebrands rolling along the ground. Then Pechanec et al (1954) plowed a final line 100 to 200 feet inside the burn, parallel to the double fireline. This uncleared strip (usually the north and east sides of a 400 to 600-acre block) was burned with backfires or strip headfires in the forenoon when the wind was 5 to 8 mph and the humidity was about 40% during late August. After the uncleared strip had been burned, the remaining area was burned with a headfire, starting about 2:30 to 3:00 p.m., presumably when air temperature was above 75° F, relative humidity was 15 to 20%, and wind was 8 to 15 mph (Ralphs et al, 1976).

A burning technique similar to that of Pechanec et al (1954) was used at the Bemore Experimental Range in central Utah (Blackburn and Bruner, 1975). Their firelines varied from 20 to 150 feet, with the narrow lines being on the upwind side (Davis, 1976). Davis (1976) states that, based on theoretical values and experience, flash fuels can be expected to ignite 50 to 90 feet ahead of an advancing front in sagebrush-grass. This implies that a 100-foot fireline on the downwind side of a fire should be adequate.

Some people have used a wet line in lieu of a plowed line in cheatgrass (Bromus tectorum). This is done by wetting a line and letting the fire back away from it. This can be done easily in cheatgrass on smooth terrain. In rough topography, however, this technique would not be feasible.

Recommendation: Based on the above data and research by Ralphs et al (1976), we recommend dozing a 10 to 12-foot fireline around the area to be burned (preferably about 450 acres according to Davis, 1976). Then strip headfire a 150-foot strip on the leeward sides during the morning hours when wind is 5 to 8 mph and humidity is about 40%. As the fire backs up in heavy fuel beyond the 150-foot strip, use a pumper to put the fire out. About 2:00 p.m., headfire the remaining area when air temperature is above 75° F, relative humidity is 15 to 20%, and wind is 8 to 15 mph (Ralphs et al, 1976).

Big Sagebrush and Low Sagebrush

Where dense stands of big sagebrush are mixed with low sagebrush (Artemisia arbuscula), no firelines need to be prepared because fires won't carry in low sagebrush even during a hot day with winds up to 25 mph (Beardall and Sylvester, 1976). Thus, the burns can be conducted on warm days with gusty winds whenever it is convenient.

Recommendation: Beardall and Sylvester (1976) suggest burning in early spring when relative humidity is below 60%, wind speed is above 8 mph, and only if you have more than 600 to 700 lb/acre of fine fuel. Late summer burning has not been tested in this area because it might do considerable harm to sensitive grasses such as Idaho fescue (Festuca idahoensis).

Big Sagebrush with Snowbanks as Natural Barriers

Use the same procedure as for mixtures of big sagebrush and low sagebrush.

Pinyon-Juniper Communities

Open Stands of Pinyon-Juniper with Grass Understory

In this vegetation type, fire is only effective in killing pinyon and juniper trees that are less than 4 feet tall (Jameson, 1962; Arnold et al, 1964; Dwyer and Pieper, 1967). Moreover, as near as we can tell, at least 600 to 700 lb/acre of fine fuel is needed to carry a fire. Trees greater than 4 feet tall will not be killed unless they have accumulations of tumbleweeds at the base (Jameson, 1962).

Recommendation: Doza a fireline 10 to 12 feet wide around the area to be burned. About 450 acres would be a good-sized unit (Davis, 1976). Strip headfire a 100-foot strip on the leeward sides of the planned burn during evening or morning hours in the spring. Where fire continues to back up beyond the 100-foot strip, put it out with a pumper. Then headfire the remainder of the area when the air temperature is 70 to 74° F, relative humidity is 20 to 40%, and wind speed is 10 to 20 mph (Jameson, 1962; Dwyer and Pieper, 1967).

Closed Stands (No Grass or Shrub Understory) of Pinyon and Juniper

Mixtures of pinyon and juniper with 300 or more trees per acre in 14 to 18-inch rainfall areas can be burned on hot, windy days if prepared properly (Truesdell, 1969; Blackburn and Bruner, 1975). However, closed stands of juniper are almost impossible to burn (Blackburn and Bruner, 1975) and would probably require winds in excess of 35 mph to carry a fire. As the proportion of pinyon to juniper increases and density increases, the stands are easier to burn (Truesdell, 1969; Blackburn and Bruner, 1975).

Recommendation: Where firebrands are not a problem on a hot day (i.e., burning into the Grand Canyon or on top of a mesa), prepare dense stands of pinyon and juniper for burning in March or April by clearing a strip 20 to 50-feet wide and pushing a windrow against the green trees every 0.25 mile on the windward side and letting the material cure for 60 to 90 days. Then in late June or early July, burn when temperatures vary from 80 to 95° F, relative humidity is 4 to 8%, and winds exceed 8 mph (Truesdell, 1969; Blackburn and Bruner, 1975).

Where firebrands are of concern or the pinyon-juniper stands are predominantly juniper, a more acceptable method of killing trees in closed stands may be to chain, burn, and seed (Aro, 1971; Stinson, 1978). Two or three months after chaining, pinyon and juniper can be burned with little risk when the wind is blowing into an untreated closed stand or a recently treated area with little fine fuel. Conditions for such burning where juniper is predominant should be when the air temperature is 90 to 100° F, relative humidity is less than 10%, and wind is 8 to 10 mph (Stinson, 1978). If pinyon pine is a major component, lower temperatures and less wind might be desired or at least the lee sides of the area ought to be burned out (200 feet) during the morning hours when the fire danger is low (Stinson, 1978).

It takes large crews to do this latter kind of burning because much of the material is in piles or windrows. Advantages of burning chained areas is to remove the trash and young trees, which provide an ideal microenvironment for the establishment of pinyon and juniper seedlings (Meagher, 1943), and to provide a good seedbed.

Another alternative for dense stands with mixtures of pinyon and juniper would be to use chaining as a method to construct firelines (Davis, 1976). The necessary width is not known, but presumably a 100 to 200-foot line would be adequate because glowing embers should not be a problem. Only the flaming embers would be of concern. The lines could be chained in the winter and then burned under moderate conditions in the spring or summer when surrounding vegetation is green (Davis, 1976). Weather with temperatures of 60 to 75° F, wind speed less than 8 mph, and relative humidity above 25% should be adequate for burning such firelines, although this has not been documented. It would seem preferable to burn under cool conditions so that most of the manpower force could be used to light the dead material rather than to patrol for spotfires.

After the firelines have been burned out, then the windrows (also prepared in winter) on the upwind side could be lit on a dry, hot, windy day in June or July. Air temperatures should be 80 to 95° F, relative humidity 4 to 8%, and wind speed in excess of 8 mph.

Mixture of Pinyon-Juniper and Sagebrush

Mixtures of sagebrush and pinyon-juniper are common throughout the Great Basin. Dense patches of pinyon-juniper and sagebrush that may vary in size from 5 to 60 acres can easily be burned without preparing firelines (Bruner and Klebenow, 1978).

Recommendation: Klebenow and Bruner (1976) have found that mixtures of pinyon-juniper and sagebrush with a total shrub and tree cover of 45 to 60% can be burned when spring air temperatures vary from 60 to 75° F, relative humidity is below 25%, and maximum wind speeds vary from 5 to 25 mph. They recommend using the "White Pine County Formula" to determine whether or not to burn (Bruner and Klebenow, 1978) where,

$$\text{Index} = \text{Maximum Wind (mph)} + \text{Shrub and Tree Cover (\%)} + \text{Air Temperature (° F)}.$$

If the index is 110 or higher, a fire will carry and will kill large pinyon and juniper trees. If the index is above 130, it is too dangerous to burn.

Chapter VIII

THE ROLE AND USE OF FIRE IN
SAGEBRUSH-GRASS AND PINYON-JUNIPER PLANT COMMUNITIES

A-STATE-OF-THE-ART-REVIEW

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Cooperation with the
FIRE AND MULTIPLE USE
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PROGRAM

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SAGEBRUSH-GRASS COMMUNITIES

Introduction

Sagebrush-grass vegetation covers at least 96.5 million acres in the western United States as estimated by the U.S. Forest Service in 1936, but considerably less than the 270 million acres estimated by Beetle in 1960 (Tisdale et al, 1969). The largest contiguous area lies in eastern Oregon, southern Idaho, southwestern Wyoming, northern Utah, and northern Nevada, although sagebrush-grass communities are widely distributed in western North America (Vale, 1975). Generally, sagebrush-grass communities occur below the pinyon-juniper zone in Nevada, Utah, and Oregon, but in the absence of a pinyon-juniper zone, sagebrush-grass vegetation will border curleaf mahogany (Cercocarpus ledifolius), oak-brush (Quercus gambelii), ponderosa pine (Pinus ponderosa), or Douglas-fir (Pseudotsuga menziesii).

Fire History

Before the influence of man, the average frequency of fire across contiguous units of sagebrush-grass communities in northern Yellowstone National Park was 32 to 70 years (Houston, 1973). Within a large general area, however, some kind of fire occurred at least every 17 to 41 years.

Dating all fires that occurred within a locale, Houston theorized that the frequency of fire in sagebrush communities was 20 to 25 years. This estimated frequency was based on the thinking that the record of fire scars for any one tree underestimated the frequency of fire because not all trees were scarred by every fire. In view of his findings that many similar fire dates occurred among trees, which were not common to all, one may also reason that once an area was burned during a dry period it is unlikely that these areas would have sufficient fuel to reburn for several years.

Based on the vigorous response of horsebrush (Tetradymia canescens) to fire and the 30 plus years that are needed for it to decline to a low level after a fire (Harniss and Murray, 1973), we feel that an acceptable frequency of fire would be about 50 years. If fires occurred every 20 to 25 years, as Houston implies, many sagebrush-grass communities would be dominated by horsebrush and rabbitbrush.

Distribution, Climate, Soils, and Vegetation

Elevation of the major sagebrush-grass zone from 2,000 to 7,000 feet, although it occurs below 1,000 feet in south-central Washington and British Columbia and mixes with all vegetative zones to varying degrees above 7,000 feet. This includes the sub-alpine hermland. Annual precipitation is 8 to 20 inches (Tisdale et al, 1969). Soil texture varies from loamy sand to clay (Tisdale et al, 1969), which interacts with precipitation and elevation to form many distinct combinations of sagebrush-grass communities. Most soils are derived from basalt, although considerable areas have soils derived from rhyolite (southeastern Oregon and Nevada), loess, lacustrine, alluvium, and limestone.

Three subspecies of big sagebrush--basin big sagebrush (Artemisia tridentata subsp. tridentata), Wyoming big sagebrush (Artemisia tridentata subsp. wyomingensis), and mountain big sagebrush (Artemisia tridentata subsp. vaseyana)--

dominate this zone. Basin big sagebrush (3.5 to 15 feet tall) and Wyoming big sagebrush (1.5 to 2.5 feet tall) are the dominants from 2,000 to 7,000 feet, with the latter being the most drought tolerant and the most palatable (McArthur et al, 1974). Basin big sagebrush occupies a 10 to 16-inch precipitation zone on deep, well drained alluvial soils, whereas Wyoming big sagebrush occupies an 8 to 12-inch precipitation zone on shallow soils (Tisdale et al, 1969). Mountain big sagebrush (2.5 to 4 feet tall) is the most mesic subspecies and can be found at elevations from 5,000 to 10,000 feet (McArthur et al, 1974) where precipitation varies from 14 to 20 inches/year. Generally, it is found above 6,500 feet.

Other species of sagebrush in decreasing order of economic importance are low sagebrush (A. arbuscula), three-tip sagebrush (A. tripartita), black sagebrush (A. nova), silver sagebrush (A. cana subsp. viscidula and A. cana subsp. bolanderii), alkali sagebrush (A. longiloba), Bigelow sagebrush (A. bigelowii), and scabland sagebrush (A. rigida) (Tisdale et al, 1969; McArthur et al, 1974). The first three generally grow below 6,000 feet elevation, although they can occur at higher elevations. Low sagebrush occurs on shallow soils or those that possess a restrictive B horizon largely in southern Idaho, Nevada, southeastern Oregon, and northeastern California (Fosberg and Hironaka, 1964). Three-tip sagebrush occurs east of this region on very mesic or dry soils in a precipitation zone of 10 to 16 inches. Black sagebrush is usually associated with calcareous soils on dry sites, but can occur as high as the Douglas-fir zone in eastern Idaho. Silver sagebrush occurs primarily in spring-flooded bottomlands. All species except three-tip sagebrush and silver sagebrush are nonsprouters. Three-tip sagebrush is a weak sprouter and silver sagebrush is a vigorous sprouter.

Major shrubs associated with big sagebrush include antelope bitterbrush (Purshia tridentata), horsebrushes (Tetradymia spp.), rabbitbrush (Chrysothamnus sp.), and broom snakeweed (Xanthocephalum sarothrae). Spiny hopsage (Grayia spinosa) and mormon tea (Ephedra nevadensis) are sporadically present in the lower rainfall areas near the Salt Desert.

Dominant grasses include bluebunch wheatgrass (Agropyron spicatum), Idaho fescue, needle-and-thread (Stipa comata), Thurber needlegrass (Stipa thurberiana), and Indian ricegrass (Oryzopsis hymenoides). All of these species or only one may be present in a particular understory. Needle-and-thread and Indian ricegrass dominate sandy soils throughout the sagebrush-grass zone. On other soils bluebunch wheatgrass dominates areas with moderate precipitation (9 to 14 inches) and Idaho fescue dominates the most mesic sites (generally more than 14 inches of precipitation). Temperature interacts with precipitation so the moisture threshold that separates bluebunch wheatgrass from Idaho fescue can vary from 12 to 16 inches of precipitation annually. Thurber needlegrass occurs on medium textured soils in an 8 to 12-inch precipitation zone. Sandberg bluegrass (Poa sandbergii) and bottlebrush squirreltail (Sitanion hystrix) are the most common subdominant bunchgrasses. Junegrass (Koeleria cristata) and other Poa sp. are also often present if the annual precipitation is above 11 inches. Rhizomatous grasses that occupy localized areas include thickspike wheatgrass (Agropyron dasystachyum), plains reedgrass (Calamagrostis montanensis), and riparian wheatgrass (Agropyron riparium). Cheatgrass (Bromus tectorum), an introduced annual, occupies millions of acres on disturbed ranges (Klemmedson and Smith, 1964), but medusahead (Taeniatherum asperum), another introduced annual, occupies the disturbed clay sites which have well developed profiles (Dahl, 1966).

Forbs are present in great variety and abundance in climax communities where the precipitation is in excess of 11 to 12 inches per year. They may account for as much as 50% of the herbaceous production in eastern Idaho, but only 5 to 15% of the herbaceous vegetation in eastern Oregon. This is why chemicals, at least in our opinion, are undesirable to manage sagebrush-grass communities in eastern Idaho where balsamoroot (Balsamorhiza sagittata) and lupine (Lupinus sp.) are typically the most abundant forbs. In eastern Oregon, groundsel (Senecio sp.), tapertip hawkbeard (Crepis acuminata), western yarrow (Achillea millefolium), and loco weed (Astragalus sp.) are the most common forbs and recover within 3 to 4 years after the use of herbicides (Forrest A. Sneva, Squaw Butte Station, Burns, Oregon).

Ecological Effects of Fire

The effect of fire on grasses depends largely on their growth form and season of burning. Bunchgrasses with densely clustered culms, such as Idaho fescue and needle-and-thread, can be severely harmed by fire (Blaisdell, 1953; Wright, 1971), and even more so if burned during June or July (Wright, 1971). Late summer or fall burns are the least harmful. The reason that these plants are killed so easily is that their dense culms will burn for 2 to 3 hours after a fire passes. Temperatures as high as 1,000° F will be reached 45 minutes after a fire has passed (Wright, 1971). Thus, many plants often die or have only a few culms that survive, regardless of the intensity of the passing fire. Thread-leaf sedge (Carex filifolia) also has a compact growth form and is severely harmed by fire (Vallentine, 1971). Preliminary research in eastern Oregon indicates that Idaho fescue is not as sensitive to fire as it is in southern Idaho. Carlton M. Britton, Squaw Butte Experiment Station, Burns, Oregon and David L. Caraher, Crooked River National Grasslands, Prineville, Oregon feel that Idaho fescue will recover in 2 to 3 years if burned when the soil is moist.

Bluebunch wheatgrass, bottlebrush squirreltail, and the crested wheatgrasses (Agropyron cristatum, A. desertorum, and A. sibericum) are less susceptible to fire than Idaho fescue or Stipa sp. (Blaisdell, 1953; Conrad and Poulton, 1966; Wright, 1971; Vallentine, 1971) because they are composed primarily of coarse stems with some leafy material. They burn very quickly with little heat going below the soil surface (Wright, 1971). Often Sandberg bluegrass and bottlebrush squirreltail are small plants in climax communities, which aids their survival after a fire (Wright and Klemmedson, 1965). Thus, they usually increase in abundance after a fire. All rhizomatous grasses such as thickspike wheatgrass and plains reedgrass increase immediately after a fire in relation to other species (Blaisdell, 1953). Production from rhizomatous grasses on a burn will be above that on control plots for about 30 years (Harniss and Murray, 1973).

Bluebunch wheatgrass will return to preburn production in 1 to 3 years (Blaisdell, 1953; Moomaw, 1957; Daubenmire, 1963; Conrad and Poulton, 1966; Uresk et al, 1976); needle-and-thread in 3 to 8 years, depending on site (Blaisdell, 1953; Dix, 1960; personal observations); and Idaho fescue in 2 to 12 or more years depending on soil moisture, season, and intensity of the fire (Blaisdell, 1953; Conrad and Poulton, 1966; Harniss and Murray, 1973; Unpublished data by C. M. Britton, Squaw Butte Experiment Station, Burns, Oregon). The response of prairie junegrass (Koeleria cristata) to fire is similar to that of needle-and-thread. Cusick bluegrass (Poa cusickii) is reduced 50% the first growing season after burning (Uresk et al, 1976). Indian ricegrass (Oryzopsis hymenoides) is only slightly damaged by fire (Vallentine, 1971).

Repeated burning every few years or burning in early summer will deplete a stand of perennial grasses and allow annual grasses, chiefly cheatgrass (*Bromus tectorum*), to increase sharply (Pickford, 1932; Wright and Klemmedson, 1965). Once sagebrush-grass is depleted to where it has no perennial plant cover, secondary succession goes from Russian thistle (*Salsola kali*) to mustard (*Sisymbrium* and *Descurainia* sp.) to cheatgrass in a period of 5 years (Piemeisel, 1951). June and July burns reduced cheatgrass plant numbers to 14 and 11/ft² compared to 41, 45, and 124 plants/ft², respectively on August, October, and November burns in Boise, Idaho (Pechanec and Huft, 1945). This is only a temporary setback for cheatgrass at a time of the year when climax perennials can be killed by fire (Wright and Klemmedson, 1965). Reclamation of such areas can only be achieved by chemical-fallow techniques (Eckert and Evans, 1967) or plowing and then seeding. Most seeding has been done with wheatgrasses (Huft, 1971). Fairway wheatgrass (*Agropyron cristatum*), crested wheatgrass (*A. desertorum*), and siberian wheatgrass (*A. sibericum*) are well adapted to this zone. Fairway wheatgrass is best adapted to moderately mesic sites and siberian wheatgrass is best adapted to the driest sites in the 8 to 12-inch precipitation zone.

Areas that are primarily sagebrush and cheatgrass can be successfully seeded directly after fire if the fire burns hot enough to consume the sagebrush plants (Young et al, 1976). Otherwise much live cheatgrass seed remains and chemical-fallow techniques (Eckert and Evans, 1967) or plowing after spring germination is desirable before drilling with perennial wheatgrasses.

Fall burning does not harm most forbs because many of them are dry and often disintegrated by this time. However, some forbs remain green and are very susceptible to fire (Table 1). Unpublished data in Utah shows that late summer or fall burning can kill Indian paintbrush (*Castilleja angustifolia*) (Neil, C. Frischknecht, Intermountain Forest and Range Experiment Station, Ephraim, Utah).

After 12 years, Blaisdell (1953) found that only the heavy sagebrush-grass burn supported more forbs than the control. By the end of 30 years, forbs had returned to preburn levels (Harniss and Murray, 1973), although both burned and unburned plots contained at least five times as many forbs as before the burn.

Fires can have a devastating and long-lasting effect of shrubs in sagebrush-grass communities. Big sagebrush, a nonsprouter, is highly susceptible to fire (Pickford, 1932; Blaisdell, 1953). Blaisdell found that the production of this species on burned areas in Idaho was only 10% of that on the control 12 years after the burn, but was near preburn levels 30 years after the burn (Harniss and Murray, 1973). Some areas, however, recover much more quickly. These differences may be related to season of burn as it affects seed production (Johnson and Payne, 1968), summer precipitation, and completeness of burn. Three-tip sagebrush is also damaged by fire, but some plants resprout (Blaisdell, 1953).

Antelope bitterbrush is severely damaged by burning (Blaisdell, 1953; Pechanec et al, 1954; Countryman and Cornelius, 1957; Nord, 1965). In Idaho 12 to 15 years after a burn, antelope bitterbrush was still only producing 50 to 60% as much as the control (Blaisdell, 1953). If soil is wet at the time of burn or shortly after the burn, resprouting of this bitterbrush occurs regularly (Blaisdell, 1953; Blaisdell and Mueggler, 1956; Nord, 1965), except on pumice soils in eastern Oregon. If the plants resprout, they will regain original growth in 9 to 10 years (Blaisdell, 1953). Where fires are not followed by rain,

antelope bitterbrush seldom sprouts. However, in southern California, desert bitterbrush (*P. glandulosa*) resprouts vigorously and abundantly (Nord, 1965) even when postfire rains are lacking.

Table 1 Susceptibility of Forbs to Fire by Three Classifications at Dubois, Idaho (Pechanec et al, 1954).

Severely damaged	Slightly damaged	Undamaged
Antennaria dimorpha	Astragalus sp.	Achillea lanulosa
Antennaria microphylla	Castilleja angustifolia	Allium sp.
Arenaria uintahensis	Crepis acuminata	Arnica fulgens
Erogeron engelmannii	Geranium viscosissimum	Balsamorhiza sagittata
Eriogonum caespitosum	Lupinus caudatus	Comandra umbellata
Eriogonum heracleoides	Penstemon radicosus	Erigeron corymbosus
Phlox canescens	Sphaeralcea munroana	Lupinus leucophyllus
		Phlox longifolia
		Senecio integerrimus
		Sisymbrium linifolium
		Zygadenus paniculatus

Other species severely damaged by fire include cliffrose (*Cowania mexicana*), curleaf mountain mahogany (*Cercocarpus ledifolius*), granite gilia (*Gilia pungens*), and broom snakeweed (*Xanthocephalum sarothrae*) (Pechanec et al, 1954; Vallentine, 1971). Mountain snowberry (*Symphoricarpos oreophilus*) appears to be somewhat harmed by burning but shows no change 15 years after burning (Pechanec et al, 1954; Blaisdell, 1953). Oregon grape (*Mahonia repens*) is favored by burning, especially after intense fires (Blaisdell, 1953).

Rabbitbrush (*Chrysothamnus* sp.), a common genus in the sagebrush-grass zone, is usually enhanced by fire (Cottam and Stewart, 1940; Blaisdell, 1953; Countryman and Cornelius, 1957; Chadwick and Dalke, 1965; Young and Evans, 1974). An exception to this general response is based on two observations by Robertson and Cords (1957) for rubber rabbitbrush (*Chrysothamnus nauseosus*). This species showed no recovery 2 years after a burn on September 3, 1942 near Mono Lake, California and after a burn on November 7, 1943 near McGill, Nevada. However, a burn in the latter area was repeated the following year on the same date and 95% of the plants resprouted. Generally, this is what we expect to happen, but obviously there are conditions under which rubber rabbitbrush can be killed.

Chrysothamnus puberulus, *C. bloomeri*, *C. lanceolatus*, and *C. viscidiflorus* all resprout vigorously. Generally, production is reduced for 1 to 3 years after burning, then it increases dramatically. On the U.S. Sheep Station near Dubois, Idaho, burning reduced production 59% the first year after burning (Blaisdell, 1953). Three years after burning, production doubled and was tripled at the end of 12 years (Blaisdell, 1953). Similarly Chadwick and Dalke (1965) found that the cover of *C. viscidiflorus* had increased four to nine times on 8 to 18-year-old burns on sandy soils in northeast Idaho. Production of *C. bloomeri* doubled 5 years after a burn in northern California (Countryman and Cornelius,

1957). In western Nevada, Young and Evans (1974) found that green rabbitbrush (C. viscidiflorus var. viscidiflorus) continued to dominate burns and reestablish itself periodically for 15 years. Communities 40 to 50 years old were dominated by big sagebrush and contained reduced populations of green rabbitbrush.

Production of horsebrush (Tetradymia canescens) was reduced about 50% the first year after burning, but doubled at the end of 3 years (Blaisdell, 1953). At the end of 12 years it had increased 5-fold. After 30 years many of these plants were dying out, but their production was still 60% above the control (Harniss and Murray, 1973). Fire greatly enhances the dominance of this species.

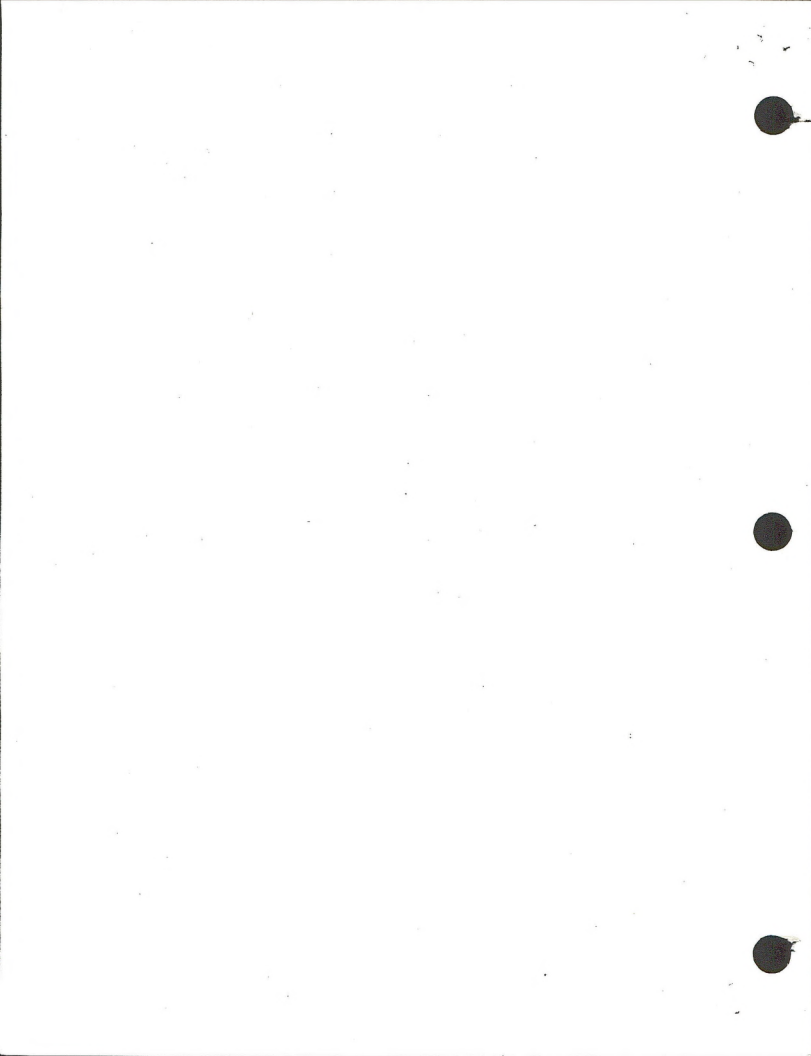
Desirable shrubs such as serviceberry (Amelanchier alnifolia), snowbrush ceanothus (Ceanothus velutinus), and true mountain mahogany (Cercocarpus montanus) are not damaged by fire (Valentine, 1971).

Management Implications

Prescribed fire can be a useful tool in many big sagebrush communities if the fires are carefully planned and livestock use after the burn is delayed for two growing seasons. Removal of thick sagebrush by fire will greatly enhance movement of livestock, reduce competition, and result in increased yields of grasses and forbs. However, depending on the vegetation, fires should not be too frequent and should be planned in early spring or after late summer. Caution should be exercised where antelope bitterbrush is dominant and where there are high resident populations of horsebrush or rabbitbrush. Where forbs are abundant or sagebrush is thick, fire is highly preferred over chemical treatments as a management tool.

It appears that much burning can be done in the sagebrush-grass region without firelines. This is especially true where patches of big sagebrush grow in swales or small ravines among low sagebrush. Fires will not carry in low sagebrush when winds are 20 mph, so they can be used as firebreaks when the big sagebrush is being burned. This is highly desirable because only the most productive sites are being burned. Similarly, early spring burning can be done at higher elevations in pure stands of big sagebrush where snow patches can be used as firelines. This is desirable for game management, but livestock should be carefully managed because animals will concentrate on the open areas.

Fires in combination with seeding can be used to suppress medusahead, but they cannot be used very successfully in combination with seeding where cheatgrass is dominant, unless it has an overstory of sagebrush. Most cheatgrass areas will need to be treated with chemicals or plowed and then seeded, if perennials are desired. Fire will not encourage native perennials in pure stands of cheatgrass, nor will pure stands of cheatgrass revert back to native perennials with rest.



State of the Art

We know generally how most shrubs and herbaceous species are going to respond to fire in sagebrush-grass communities, but more information is needed on bluebunch wheatgrass, Idaho fescue, and the big sagebrush subspecies. Fire intensity, season of burn, plant size, and soil moisture status should be evaluated at a variety of bluebunch wheatgrass and Idaho fescue locations for several years. More long-term data following fires is badly needed for Idaho fescue.

Big sagebrush subspecies will sometimes invade burned areas rapidly and sometimes very slowly. McDonough and Harniss (1974) have done some work on the germination requirements of big sagebrush but more studies are needed. Timing of burns in relation to seed maturity of sagebrush, residual seed supply in soil after various intensities of heat, and response of sagebrush seed to soil moisture over a period of years all need to be evaluated. Seed dispersal distance of sagebrush plants has been studied by Frischknecht (1962). He found that the mean distance of maximum spread of big sagebrush seed was 42 feet from parent plants.

We also need more research on spring vs. fall burns. Where forbs are not important in plant communities, early spring burning may be more desirable for bunchgrasses than later summer or fall burns.

Prescription data for sagebrush-grass burns have been given by Pechanec et al (1954) and more recently by Ralphs et al (1976). Nevertheless, the data are meager. We will need more data on prescribed burning techniques before fire can be used economically. Desired width of firelines is still a question, and the potential for spotfires in sagebrush-grass communities needs to be more thoroughly documented, although sagebrush is less volatile (Powell, 1970) than chamise and piñon-juniper.

PINYON-JUNIPER COMMUNITIES

Introduction

The pinyon-juniper association covers from 43 to 76 million acres in western North America, depending on whether you use Kuchler's (1964) map of potential pinyon-juniper woodland (the lower figure) or the earlier Senate Document 199 (Clapp et al, 1936) where all western lands then having juniper, with or without pinyon pines, were included. West et al (1975) have taken a liberal definition of pinyon-juniper woodlands and included both Kuchler's "juniper-pinyon woodlands" and "juniper steppe" types, plus the areas within the Great Basin sagebrush, sagebrush-grass steppe, and the Trans-Pecos shrub savannah. Leaving out the juniper woodlands in Texas, the figure by West et al (1975) for the western United States is 75 million acres. These lands are located below the oakbrush (Quercus gambelii) and ponderosa pine (Pinus ponderosa) zones, but above the sagebrush (Artemisia sp.) or grassland areas where juniper, more xeric than pinyon, is continually spreading.

Fire History

The historic role of fire in controlling the distribution of pinyon-juniper, particularly juniper, cannot be separated from the effect of drought and competition (Leopold, 1924; Johnsen, 1962). All occurred simultaneously and seemed to have played a complementary role in limiting the distribution of juniper before domestic livestock were a factor. However, droughts and competition from grass probably served only to slow the invasion and growth of junipers in adjacent grasslands, since the trees are easily established during wet years (Johnsen, 1962; Smith et al, 1975), especially where shade is present (Meagher, 1943). Then fire, occurring about every 19 years (Leopold, 1924) or possibly as long as 30 years, kept the junipers restricted to shallow, rocky soils and rough topography (Arend, 1950; Burkhardt and Tisdale, 1969). For the last 70 years, however, heavy livestock grazing has reduced grass competition as well as fuel for fires and has permitted pinyon and juniper to invade adjacent communities rapidly and unchecked.

The above leads one to believe that fire has tremendous potential as a tool to reclaim grasslands that have been invaded by juniper and where overgrazing has led to closed stands of pinyon-juniper, but not in rough breaks where the fine fuels are inadequate to carry a fire (Burkhardt and Tisdale, 1969; O'Rourke and Ogden, 1969). Aro (1971) concluded that burning was the most effective and least expensive method available to convert pinyon-juniper to grassland.

Blackburn and Bruner (1975) mentioned that prescribed burning has been used in pinyon-juniper communities several ways: (1) burning slash and debris left after the use of other methods of control; (2) burning individual trees where neither the trees nor the understory plants are dense enough to carry a fire; (3) burning grassland or sagebrush-grassland to kill invading trees; and (4) broadcast burning mature trees. Broadcast burning has also been used to kill trees less than 4 feet tall in grasslands (Jameson, 1962; Dwyer and Pieper, 1967).

Distribution, Climate, Soils, and Vegetation

True pinyon-juniper woodlands extend from the east slope of the Sierra Nevada Mountains, eastward throughout mountains of the Great Basin in Nevada and Utah, and on both flanks of the Rocky Mountains in Colorado (as well as mesas of the Colorado Plateau and interior valleys), then southward into Arizona, New Mexico, and northern Mexico (Rasmussen, 1941; Johnsen, 1962). Dense stands of juniper alone that join the pinyon-juniper woodlands extend further north into eastern Oregon and southern Idaho and Wyoming.

Pinyon-juniper woodlands are generally found at elevations from 4,500 to 7,500 feet (Springfield, 1976), but they are best developed between 5,000 and 7,000 feet (Woodbury, 1947). Nevertheless, pinyon-juniper may be found growing from 2,500 to 3,000 feet in the upper parts of deserts (Johnsen, 1962; Franklin and Cynness, 1969) to 9,000 feet in ponderosa pine forests (Lanner, 1975). The highest elevation for pinyon-juniper woodland is nearly 10,000 feet in the White Mountains of California where the Sierra Nevada Mountains create an extreme rain-shadow effect (St. Andre et al, 1965). The upper altitudinal limit of the pinyon-juniper zone is determined by low temperature and the lower range by a deficiency in moisture (Pearson, 1920).

Annual precipitation varies from 10 to 15 inches over most of the pinyon-juniper zone where stands are open (Woodbury, 1947), but dense stands may receive 16 to 22 inches of rain and snow (Springfield, 1976). On xeric sites at high elevations, annual precipitation of pinyon-juniper communities may be as high as 26 inches (Pearson, 1931). Pinyon (*Pinus edulis* and *P. monophylla*) is usually most abundant at the higher elevations of the pinyon-juniper zone with a mixing of pinyon and juniper at mid elevations (Reveal, 1944; West et al, 1975; Springfield, 1976). Since pinyon is very susceptible to fire (Leopold, 1924), as well as the more mesic of the two genera, fire is probably an additional factor that keeps pinyon out of the lower elevations.

Distribution of the pinyon-juniper association is not limited by parent material (Emerson, 1932; Springfield, 1976) or soil texture (Pearson, 1931; Springfield, 1976). The trees grow on residual and transported soils derived from sandstone, limestones, basalt, granite, and mixed alluvium (Springfield, 1976). Soil textures vary from stony, cobbly, and gravelly loams to clay loam and clay, and depth from shallow to deep (Springfield, 1976), but the best stands of pinyon are found on coarse gravel, gravelly loam, or coarse sands (Phillips, 1909). The soils are generally calcareous and alkaline, but juniper can grow easily on acid soils down to a pH of 4.7 (Arend, 1950). Except for those soils derived from basalt, most are low in fertility (Howell, 1941; Springfield, 1976) and often shallow and rocky.

Dominant tree species of the pinyon-juniper woodlands are Utah juniper (*Juniperus osteosperma*), one-seed juniper (*J. monosperma*), Rocky Mountain juniper (*J. scopulorum*), alligator juniper (*J. deppeana*), doubleleaf pinyon (*Pinus edulis*), and singleleaf pinyon (*P. monophylla*). Doubleleaf pinyon is associated with the southern Rocky Mountains and extends westward to the eastern edge of the Great Basin. Throughout the Great Basin, eastern slope of the Sierra Nevada Mountains, and western portions of Arizona singleleaf pinyon is associated primarily with Utah juniper.

Utah juniper is the most important species in the pinyon-juniper woodland (Fanner, 1975). It is distributed in northern Arizona, Utah, Nevada, and parts of California. One-seed juniper extends from central Colorado to central Arizona and is widely distributed throughout most of New Mexico. A little occurs in the Palo Duro Canyon of west Texas. Alligator juniper, a sprouting species, is also widespread in the Southwest. It is abundant in Mexico and reaches its northern limits in north-central Arizona and New Mexico. Rocky Mountain juniper occurs only at the higher elevations of the pinyon-juniper woodland (Fanner, 1975).

Outside of the pinyon-juniper woodland, western juniper (*J. occidentalis*) is very abundant in eastern Oregon. East of New Mexico, additional species of juniper such as redberry juniper (*J. pinchoti*), a sprouting species, Ashe juniper (*J. ashei*), and eastern red cedar (*J. virginiana*) are abundant in some areas. These species are often associated with rocky slopes such as escarpments, ridges, or rimrocks throughout the Great Plains (Wells, 1970), and alkaline soils such as the Edwards Plateau in central Texas. From the rocky areas where juniper is considered to be the climax in the Plains, trees spread rapidly into the surrounding grasslands in the absence of fire. Eastern red cedar is the most extensive species and occurs from Texas northeastward throughout most of the eastern United States.

Herbaceous species vary considerably throughout the pinyon-juniper zone. On the eastern flank of the Rocky Mountains in New Mexico, blue grama (*Bouteloua gracilis*) is the dominant herb understory with some sideoats grama (*B. curtipendula*) and wolf tail (*Lycurus phleoides*) and a few forbs often intermixed (Pieper et al., 1971). In north-central Arizona, blue grama and sideoats grama remain as dominant grasses, but prairie junegrass (*Koeleria cristata*), bottlebrush squirreltail (*Sitanion hystrix*), muttongrass (*Poa fendleriana*), and black dropseed (*Sporobolus interruptus*) are important components (Clary, 1971). Other sites include desert needlegrass (*Stipa speciosa*) (Thatcher and Hart, 1974), red three-awn (*Aristida longiseta*), ring muhly (*Muhlenbergia torreyi*) (Jameson and Reid, 1965), and western wheatgrass (*Agropyron smithii*) (Clary and Morrison, 1973). Forbs and half shrubs make up about 50% of the herbaceous composition in north-central Arizona. Broom snakeweed (*Xanthocephalum sarothrae*), sulfur eriogonum (*Eriogonum cognatum*), plumeweed birdbeak (*Cordylanthus wrightii*), and goldeneye (*Viguiera* sp.) are dominants (Clary, 1971).

Northward, warm season grasses drop out of the understory. In southwestern Colorado in Mesa Verde National Park, the meadow stage (4 years after burning) is dominated by Indian ricegrass (*Oryzopsis hymenoides*), bottlebrush squirreltail, and muttongrass (Erdman, 1970). Forbs and shrubs are also present at various stages of succession after burning. In Utah, bluebunch wheatgrass (*Agropyron spicatum*) and western wheatgrass are the most abundant grasses with lesser amounts of Sandberg bluegrass (*Poa sandbergii*), bottlebrush squirreltail, and Indian ricegrass (Barney and Frischknecht, 1974). Forbs are a minor component.

In Nevada, a variety of sources (Blackburn et al., 1969; Jensen, 1972; Klebenow et al., 1976) indicate that common grasses include bottlebrush squirreltail, Sandberg bluegrass, needle-and-thread (*Stipa comata*), Great Basin wildrye (*Elymus cinereus*), and cheatgrass (*Bromus tectorum*). Other grasses included western wheatgrass, Indian ricegrass, and Thurber needlegrass (*S. thurberiana*). Forbs vary widely in species and abundance but can include *Lupinus* sp., *Phlox* sp., *Aster* sp., *Senecio* sp., *Eriogonum* sp., *Ranunculus* sp., *Cryptantha* sp., *Mentzelia* sp., *Eriastrum* sp., *Castilleja* sp., *Machaeranthera* sp., *Argemone* sp., *Sphaeralcea* sp., *Nicotiana* sp., *Lygodesmia* sp., and *Chenopodium* sp.

Further north in eastern Oregon, bluebunch wheatgrass and Idaho fescue (*Festuca idahoensis*) are the dominant grasses (Franklin and Dyrness, 1969). Sandberg bluegrass and Thurber needlegrass are common. Other grasses include bottlebrush squirreltail, needle-and-thread, cheatgrass, annual fescue (*Festuca octoflora*), and prairie junegrass. Forbs are not very abundant but the most common perennial forbs are *Agoseris* sp., *Achillea millifolium*, *Eriophyllum lanatum*, *Astragalus* sp., *Erigeron linearis*, and *Lupinus* sp.

Herbage yields of pinyon-juniper stands can vary considerably depending on surface texture of soil and stage of succession (Thatcher and Hart, 1974). Soils with a vesicular, massive, or platy surface layer may have very little grass regardless of the stage of plant succession (Thatcher and Hart, 1974). However, a reasonable average herbage yield for plant communities with moderate amounts of pinyon-juniper seems to be 600 lb/acre (Jameson and Reid, 1965; Jensen, 1972; Pieper et al, 1971; Clary, 1971). Yields on good soils with good precipitation can be as high as 1,400 lb/acre (Pieper et al, 1971; Springfield, 1976).

Shrubs that dominate the understory of pinyon-juniper include big sagebrush (*Artemisia tridentata*), black sagebrush (*A. nova*), antelope bitterbrush (*Purshia tridentata*), shrub live-oak (*Quercus turbinella*), cliffrose (*Cowania mexicana*), Gambel's oak (*Quercus gambelii*), serviceberry (*Amelanchier* sp.), and true mountain mahogany (*Cercocarpus montanus*). Other shrubs that are associated in various amounts with pinyon-juniper include fringed sagebrush (*A. frigida*), Wright silktassel (*Garrya wrightii*), currant (*Ribes cereum*), desert peach (*Prunus andersonii*), cliffrose (*Cowania mexicana*), mountain lover (*Pachistima myrsinites*), skunkbush sumac (*Rhus trilobata*), ephedra (*Ephedra* sp.), curlleaf mountain mahogany (*C. ledifolius*), chokecherry (*Prunus virginiana*), mockorange (*Philadelphus lewisii*), pointleaf manzanita (*Arctostaphylos pungens*), winterfat (*Ceratoides lanata*), snowberry (*Symphoricarpos vaccinioides*), algerita (*Berberis fremonti*), Wright eriogonum (*Eriogonum wrightii*), rabbitbrush (*Chrysothamnus nauseosus*), Apache plume (*Fallugia paradoxa*), blackbrush (*Coleogyne ramosissima*), fourwing saltbush (*Atriplex canescens*), fringed sagebrush (*Artemisia frigida*), broom snakeweed, Dalea (*Dalea* sp.), horsebrush (*Tetradymia canescens*), and yucca (*Yucca* sp.). This wide variety of shrubs reflects the many different plant communities which pinyon-juniper buffers against, and has been taken from various references (Arnold et al, 1964; Dwyer and Pieper, 1967; Blackburn et al, 1969; O'Rourke and Ogden, 1969; Blackburn and Tueller, 1970; Erdman, 1970; Aro, 1971; Clary, 1971; Barney and Frischknecht, 1974; Klebenow et al, 1976; Springfield, 1976; Young and Evans, 1976).

Ecological Effects of Fire

Pinyon and Juniper

The effect of fire on living pinyon and non-sprouting juniper trees depends largely upon the height of trees, herbaceous fuel, weather conditions, and season. In open pinyon-juniper stands with an understory of 700 to 1,000 lb/acre of fine fuel, Jameson (1962) and Dwyer and Pieper (1967) found that pinyon and juniper were easily killed by spring fires if trees were less than 4 feet tall, when air temperature was 70 to 74° F, relative humidity 20 to 40%, and wind speed is 10 to 20 mph. Lower air temperatures in January (49 to 54° F), relative humidity 44%, and wind of 6 to 8 mph caused a very spotty burn in which crown kill varied from 30 to 70% of trees 2 to 4 feet tall, but 70% of the trees died (Jameson, 1962). A wildfire in June with an air temperature of 97° F, wind 10 to 15 mph,

and relative humidity 17 to 25% assured a 100% kill of all trees less than 4 feet tall, but was no more effective on taller trees than when air temperatures were 70 to 74° F (Jameson, 1962).

Trees greater than 4 feet tall in open pinyon-juniper stands are difficult to kill unless you have excess accumulations of fine fuel beneath the trees. On the wildfire studied by Dwyer and Pieper (1967), only 24% of the pinyon and 13.5% of the juniper which exceeded 4 feet died. Jameson (1962) found that most juniper over 4 feet tall only had a 30 to 40% crown kill, unless tumbleweeds had accumulated at the base of the trees. Then 60 to 90% of the crowns were killed, particularly for trees 8 to 10 feet tall. East of the pinyon-juniper zone in Texas, juniper trees up to 12 feet tall were easily killed when fine fuel was 2,000 lb/acre or higher (Wink and Wright, 1973).

Trees in closed stands of pinyon-juniper with no grass or sagebrush in the understory are difficult to kill because fires won't carry easily (Arnold et al, 1964; Blackburn and Bruner, 1975). Dense stands (495 to 988 trees/acre) in 14 to 18-inch rainfall areas with a mixture of pinyon and juniper can be burned on hot days, but pure stands of juniper are almost impossible to burn (Blackburn and Bruner, 1975). A number of people in the Great Basin area speculate that it would require winds over 35 mph to burn pure stands of juniper. Thus, many attempts to burn such stands have failed (Arnold et al, 1964; Aro, 1971). As the proportion of pinyon to juniper increases and the density increases, the stands are easier to burn (Truesdell, 1969; Blackburn and Bruner, 1975). Such areas are usually burned by clearing an area 20 to 125 feet wide and pushing a windrow against the green trees on the windward side and letting the material cure for 60 to 90 days. Then in June or July, burns are conducted when temperatures vary from 80 to 95° F, relative humidity is 4 to 8%, and winds exceed 8 mph (Truesdell, 1969; Blackburn and Bruner, 1975). These burns have been conducted on mesas or next to the Grand Canyon where firebrands were not a problem.

A more acceptable method of killing trees in closed stands of pinyon-juniper may be to chain, burn, and seed (Aro, 1971; Stinson, 1978). Two or three months after chaining, pinyon and juniper can be burned with little risk when the wind is blowing into an untreated closed stand. Conditions for such burning should be when the air temperature is 90 to 100° F, relative humidity less than 10%, and wind 8 to 10 mph (Stinson, 1978). It takes large crews to do this kind of burning because much of the material is in piles or windrows. Advantages to burning chained areas is to remove the trash and young trees, which provide an ideal microenvironment for the establishment of pinyon and juniper seedlings (Meagher, 1943), and to provide a good seedbed for grass (Aro, 1971). Seeding grass would be the last step, but is not always necessary (Aro, 1971).

A mixture of sagebrush and pinyon-juniper is common throughout the Great Basin, and it is feasible to burn and kill large pinyon and juniper trees in these communities (Bruner and Klebenow, 1978). To get a fire to carry, Bruner and Klebenow (1978) have proposed the "White Pine County Formula" where,

$$\text{Index} = \text{Maximum Wind (mph)} + \text{Shrub and Tree Cover (\%)} + \text{Air-Temperature (° F)}$$

If the index is 110 or higher, a fire will carry and will kill the large pinyon and juniper trees. If the index is above 130, it is too dangerous to burn. Most of the work by Bruner and Klebenow had been done in pinyon-juniper stands

with 45 to 60% of shrub and tree cover and burned when air temperature was 60 to 75° F, relative humidity was below 25%, and maximum wind speed was 5 to 25 mph.

Alligator juniper and redberry juniper are the only sprouting species. Smith et al (1975), found that if the tops of redberry juniper trees were removed before they reached 12 years of age, 99% mortality could be expected. Older trees were not studied. This data implies that if subjected to fire every 10 years or so, sprouting species of juniper may have a difficult time invading grasslands. Schroeder (1956) found that about 40% of alligator juniper trees less than 15 feet tall could be killed by burning individual plants (quoted by Blackburn and Bruner, 1975).

Forbs and Grasses

In Utah, the most abundant annual forbs during the first stages of succession are pale alyssum (Alyssum alyssoides), flixweed tansymustard (Descurainia sophia), sunflower (Helianthus annuus), coyote tobacco (Nicotiana attenuata), and Russian thistle (Salsola pestifer) (Barney and Frischknecht, 1974). Generally, however, none of these forbs constitute a large amount of cover on pinyon-juniper burns (Arnold et al, 1964; Barney and Frischknecht, 1974). Cheatgrass brome (Bromus tectorum) is usually the most abundant annual and have a cover value as high as 12.6% on 3-year-old burns. Thereafter, it gradually declines to 0.9% over a period of 20 years (Barney and Frischknecht, 1974). On some sites, however, cheatgrass may never show up (Klebenow et al, 1976) which might be used as a guide as to whether some areas can be reclaimed to grasses. In Nevada, tapertip hawksbeard (Crepis acuminata) and Lupinus sp. increase abundantly after fire (Klebenow et al, 1976). Balsamorhiza sp. and Castilleja sp. also come back reasonably well (Klebenow et al, 1976).

The composition of perennial grasses varies depending on the location, as discussed earlier. In the northern latitudes west of the Rocky Mountains, cool season grasses dominate with a gradual transition to the dominance of blue grama eastward in the shortgrass plains and southward in central Arizona and New Mexico. Vallentine (1971) has cited a number of authors as to the tolerance of various grasses to fire. Species that are only slightly damaged by fall fires include bluebunch wheatgrass, Indian ricegrass, galleta grass (Hilaria jamesii), bottle-brush squirreltail, Great Basin wildrye, and blue grama. Those moderately affected by fire include prairie junegrass, needle-and-thread, Thurber needlegrass, and three-awns. Species severely affected by fire include ring muhly, sideoats grama, and Idaho fescue. Sandberg bluegrass, cheatgrass, western wheatgrass, and crested wheatgrass are unaffected by fall fires.

Shrubs

Shrubs were mentioned earlier, and there are many species. Vigorous sprouters after fire include serviceberry, Wright silktassel, shrub live-oak, skunkbush sumac, true mountain mahogany, desert bitterbrush, chokecherry, mock-orange, winterfat, snowberry, algerita, rabbitbrush, fourwing saltbush, and horsebrush. Weak sprouters include antelope bitterbrush, curlleaf mountain mahogany, snakeweed, mountain lover, yucca, fringed sagebrush, and Wright eriogonum. Antelope bitterbrush and mountain lover are extremely slow in recovering after fire (Nord, 1965; McKell, 1950). Cliffrose is eliminated on burns in Nevada (Klebenow et al, 1976). Non-sprouting species include big sagebrush, black sagebrush, and blackbrush. Nevertheless, these non-sprouting species,

except for blackbrush, reestablish themselves quickly from seed. Blackbrush reestablishes itself very slowly (Jenson et al, 1960).

Succession After Fire

The general successional pattern after fire in pinyon-juniper of the Southern Rocky Mountains has been worked out by Arnold et al (1964) and most recently by Erdman (1970) and Barney and Frischknecht (1974). The order of vegetational changes in juniper woodland after fire that were found by Barney and Frischknecht are as follows: juniper woodland → fire → skeleton forest (dead trees) and bare soil → annual stage → perennial grass-forb stage → perennial grass-forb-shrub stage → perennial grass-forb-shrub-young juniper stage → shrub-juniper stage → juniper woodland.

Mature stands of juniper (100+ years) consist primarily of 35% bare ground, 19 to 60% litter which is dominated by the tree overstory that inhibits grass production (Johnsen, 1962), and a few scattered shrubs and perennial and annual grasses (Arnold et al, 1964; Clary, 1971; Barney and Frischknecht, 1974). Erosion is frequently a problem in the bare soils between trees in mature stands (Plummer, 1958). After a fire, juniper seedlings and annuals begin to invade and reach maximum abundance in the first 3 to 4 years (Arnold et al, 1964; Barney and Frischknecht, 1974). Where partial shade is present, pinyon seedlings can also be abundant (Erdman, 1970). The perennial-grass-forb stage usually follows in the fourth to sixth year. Little rabbitbrush (*Chrysothamnus viscidiflorus*) resprouts in the first year or two, and shrubs such as sagebrush (*Artemisia* sp.) and broom snakeweed (*Xanthocephalum sarothrae*) begin appearing after the sixth year in plant communities in and around the Great Basin, if they are present. In southwestern Colorado, Gambel's oak, serviceberry, true mountain mahogany, and antelope bitterbrush are the dominate shrubs (Erdman, 1970). After 40 years, the shrubs begin to die out and the cover and density of juniper increases dramatically (Barney and Frischknecht, 1974). Barney and Frischknecht (1974) found that Utah juniper begins to bear fruit for the first time at 33 years of age, which accounts for the ability of many juniper stands at 40 years of age or older to establish new trees and increase the number of trees per acre dramatically (Erdman, 1970).

Plant succession according to Erdman (1970) continues in three more stages. The open shrub stage becomes a thicket in about 100 years. As the sere progresses toward climax, the trees begin to overtop the shrubs and gradually suppress the shrubs as the forest matures. After several centuries, the understory is composed mainly of a sparse shrub component, some grass, and several forbs. A climax pinyon-juniper forest develops in about 300 years.

Management Implications

In open stands of pinyon-juniper in the Southwest, fire can be used effectively to kill pinyon and juniper trees less than 4 feet tall. Taller trees are very difficult to kill, even with hot fires, unless a lot of tumbleweeds have accumulated at the base. Thus, if pinyon and juniper trees are considered a problem in open stands, chaining or dozing would have to precede burning to kill the large trees. Burning should follow chaining or dozing to minimize the ideal microclimate for seedlings.

Reclamation of closed pinyon-juniper stands (no understory of grasses or shrubs) has been tried by several management agencies using various techniques (Jameson et al, 1964; Aro, 1971; Clary, 1971). Of all methods, prescribed burning, or some combination of burning with other treatments, followed by artificial seeding when necessary is the most effective procedure to reclaim closed stands of pinyon-juniper (Aro, 1971; Springfield, 1976). Burning without any prior treatment must be done on hot days (95 to 100° F) with low relative humidity and 8 to 20 mph winds. These conditions are too hazardous for most land managers (Arnold et al, 1964). Thus, mechanical treatment followed by burning is probably the most acceptable technique to reclaim dense stands of pinyon-juniper even though it is expensive. Burning should be delayed 2 to 3 years after chaining, after most of the pinyon and juniper seeds have germinated (Meagher, 1943).

Production of grasses will increase dramatically following burning and seeding treatments in closed stands of pinyon-juniper. Herbage yields on the Hualapi Indian Reservation in northern Arizona, seeded with crested wheatgrass, western wheatgrass, weeping lovegrass, and yellow sweetclover (Melilotus officinalis), produced 1,660 lb/acre compared to 60 lb/acre for the unburned control (Aro, 1971). On another large scale burning and seeding program in pinyon-juniper woodland, Aro (1971) reported that forage production increased 500 lb/acre. Without burning, Clary (1971) found that 5 to 11 years after chaining and seeding in northern Arizona, pinyon-juniper communities produced 981 lb/acre of grasses, forbs, and shrubs compared to 223 lb/acre for the control. Where native grasses are present in the understory, reseeding is not necessary (Aro, 1971).

Mixtures of sagebrush and pinyon-juniper can be burned without prior treatment. Generally thick stands with 45 to 60% cover are selected for burning and burned into areas with less shrub cover. Some areas are left to reseed naturally, but aerial seeding is usually considered desirable.

After conversion of pinyon-juniper stands to grassland, reburns should follow about every 20 to 30 years. A definite time is difficult to set because reinvasion of pinyon and juniper is dependent on climate, kind of treatment, initial time span between treatments, intensity of burn, and grazing intensity after the burn. A better guide would be to reburn when the tallest pinyon or juniper tree reaches a height of 4 feet.

State of the Art

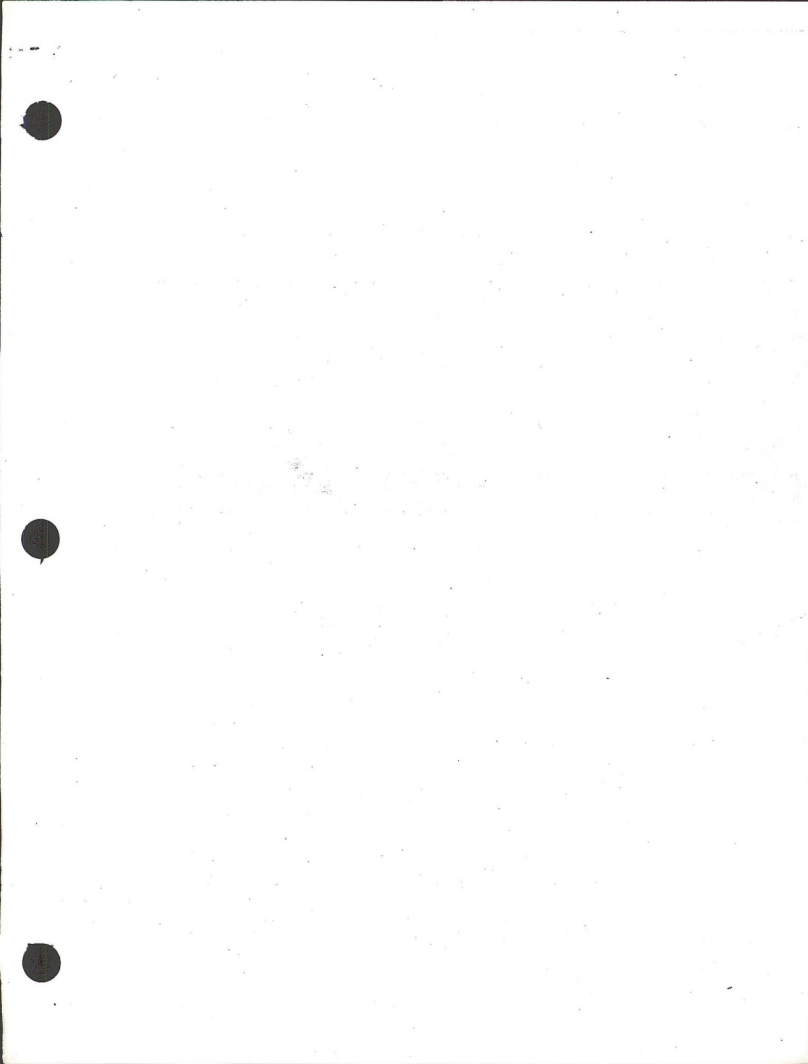
More research is needed on prescription techniques to burn closed stands of juniper and mixed stands of sagebrush and pinyon-juniper. We have some information and know generally how to approach burning prescriptions, but we are not comfortable with them. Since closed stands have been burned successfully and economically in northern Arizona without prior treatment, we need to know where this kind of burning can and cannot be done. Can the boundaries be areas with less than 200 trees per acre or areas with less than 600 lb/acre of herbaceous understory? Some reasonably concrete guides are needed.

We have reasonably good baseline data for burning mixed stands of pinyon-juniper and sagebrush with no herbaceous understory. However, we need to know more about setting the boundaries (based on cover and weather) for areas to be burned. Should firelines be prepared via chaining and burning before burning a large block of mixed sagebrush and pinyon-juniper? How wide should the firelines be?

In the open pinyon-juniper grasslands we know reasonably well what can be done. Here, information as to the minimum amount of fine fuel (herbaceous understory) that is needed to carry a fire would be helpful, although we can estimate that it is 600 to 700 lb/acre.

Our largest void of information on pinyon-juniper communities is the response of the understory species to fire. We have pieces of information, but a number of the shrubs and some cool season grasses deserve more study. Also, alligator juniper needs to be studied in more detail. We need to know how different age classes of this species respond to fire. Our present data indicates that young trees may be more susceptible to fire than the old trees.

Guidelines for reseeding burned pinyon-juniper stands would be helpful. Should drilling be done in preference to aerial seeding when possible? How much of a perennial understory in untreated pinyon-juniper is necessary before artificial reseeding with perennials is not considered necessary?



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